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THE

AMERICAN JOURNAL OF SCIENCE.

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THIRD SERIES.

VOL. XLIII.—[WHOLE NUMBER, CXLIII.]

No. 256.—APRIL, 1892.

WITH PLATE XII.

NEW HAVEN, CONN.: J. D. & E. S. DANA.
1892.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 371 STATE STREET.

Published monthly. Six dollars per year (postage prepaid). $6.40 to foreign subscribers of countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks.

A. E. FOOTE,

4116 Elm Avenue, **Philadelphia, Pennsylvania, U. S. A.**

CALIFORNIA RUBELLITES.

We have just received from a new locality in California some remarkable specimens of **Rubellite.** The well defined, columnar crystals, many of them from one to two inches long and showing distinct terminations, occur principally in radiated aggregates imbedded in a Lepidolite rock. These specimens are exquisitely beautiful, all of them presenting the same uniform shade of rose-pink in a pale lilac setting of Lepidolite, forming a combination of colors rarely equalled.

NEW MEXICO MINERALS.

From our collector in the Organ Mountains we have just received eight boxes of minerals, the result of several weeks work at the **Wulfenite** locality.

Among the finer specimens of this shipment are several large, beautiful **Aragonites** and a new type of **Wulfenite,** brownish yellow in color, occurring in crystals of from one to three inches in diameter with perfect terminating edges. Also some beautiful, transparent yellow Wulfenites with perfect terminations.

Among other recent arrivals are **Colemanites;** translucent doubly terminated **Vanadinites;** Guanajuato minerals, including **Calcites, Polybasites, Argentites** and other silver minerals. A fine lot of precious **Opals** in the matrix. From Arkansas, crystallized **Eudialyte, Perofskite** in the rock; **Manganopectolite** and fine crystals of **Pseudoleucite.**

A large and fine assortment of **Diaspores** and **Margarites.**

Polished sections of **Jasperized Wood** from Arizona. Rare and interesting crystallized Gold on Galenite from Colorado. **Cobaltite, Linnæite, Stannite, Euchroite, Libethenite** and many others.

We shall be glad to send any of the above on approval to those wishing to see them.

The new Catalogue of *Minerals and Mineralogical Books,* 128 pages, containing many illustrated scientific articles, will be sent free to all intending purchasers who request it, on headed paper and to all customers; to others it will be sent post paid on receipt of 5 cents, or on heavy paper 10 cents, bound in cloth 35 cents. Many pages are devoted to a mention of the Minerals collected by Prof. Foote in various parts of the world.

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Fig. 2

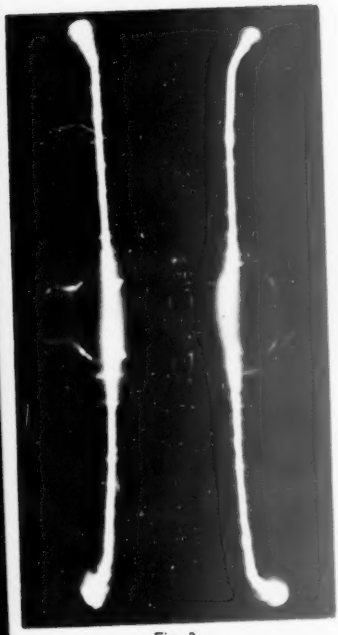


Fig. 3

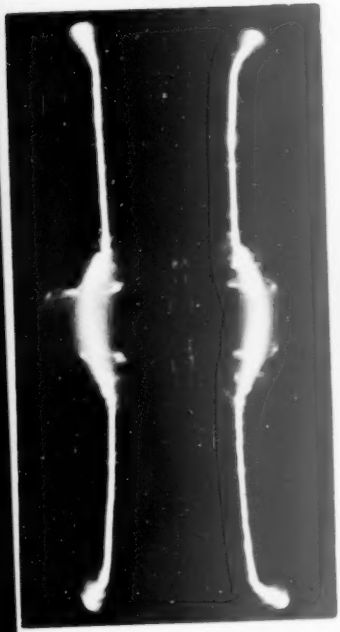


Fig. 4

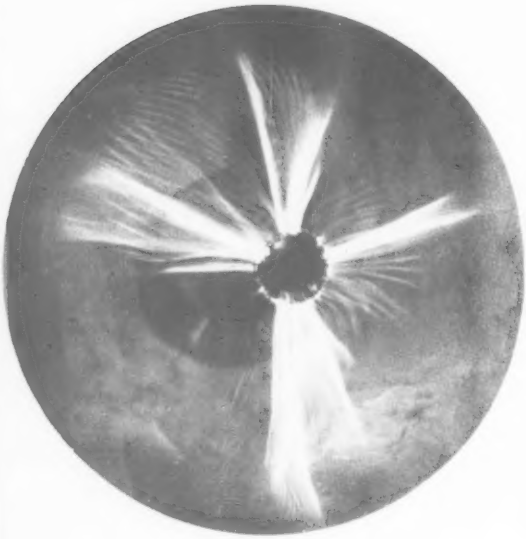
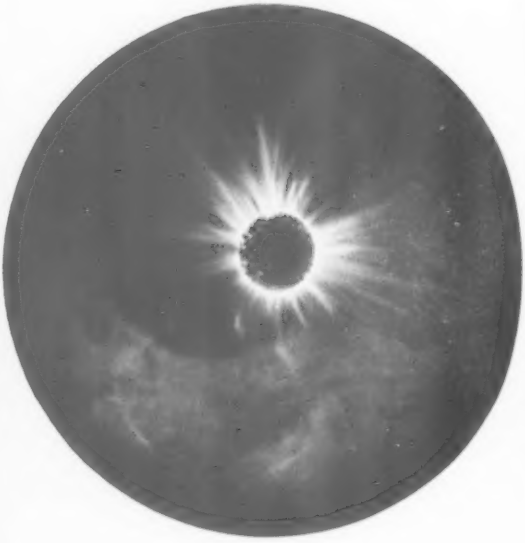


Fig. 5



THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

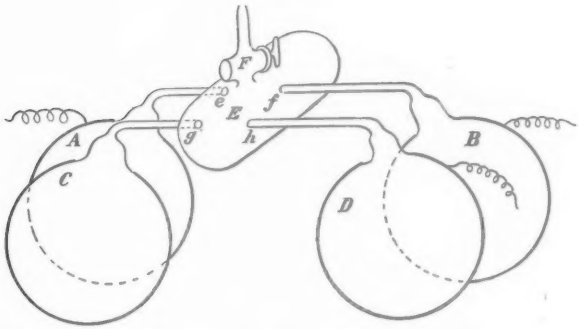
ART. XXXII. — *On the Action of Vacuum Discharge Streamers upon each other;* by M. I. PUPIN, Ph.D., of Columbia College. With Plate XII.

VARIOUS phenomena which I observed in the course of an investigation on the coronal effects produced by electrical discharges through rarefied gases, led me to the belief that under certain conditions two electric current filaments in a rarefied gas may act upon each other oppositely to the direction of their mutual electrodynamic action, and that this additional action may sometimes be far predominant over the electrodynamic action; that is to say, we have a strong repulsion where electrodynamic action would produce an attraction. A brief account of these investigations was given on Feb. 8th, before the Astronomical Section of the New York Academy of Sciences. The following paper is limited to the description of the experiments by means of which the existence of the above mentioned action was definitely proved.

Fig. 1 represents the apparatus first employed. Four glass bulbs, A, B, C, D, each having a capacity of about a liter, are connected by four glass tubes of small bore to a glass reservoir E. A stopcock F serves to connect the apparatus to a mercury pump. The reservoir has a diameter of 10^{cm} and a length of 22^{cm}. The mouths e, f, g, h, of the four narrow-bore tubes form a square whose side is 10^{cm} long. The bulbs are covered with tinfoil and the tinfoil is then well coated with paraffin.

Each tinfoil covering has a well insulated copper wire attached to it.

Fig. 1.



After producing a 2^{mm} vacuum in the apparatus the bulbs A and B were connected to the secondary poles of a small Ritchie induction coil, whose primary was fed by an alternating current of 125 periods per second. The electromotive force in the secondary coil was varied by varying the current in the primary; this was done by means of a resistance box in the primary circuit. The electric flow between the bulbs is, of course, due to the condenser effect between the tinfoils and the vacuum.

At the pressure of 2^{mm} the discharge was easy, steady and very diffuse along its path through the reservoir. Disconnecting AB and connecting CD to the induction coil the discharge was the same in character as before. Connecting both pairs of bulbs in parallel to the induction coil, that is, the bulbs A and C to one pole and B and D to the other pole, the two discharges, going on simultaneously, were the same in character as before, except that they were somewhat convex towards each other.

The pressure was then increased by turning the stopcock once around and allowing some air to get in. The discharges were less diffuse but more luminous, and less convex toward each other.

With the increase of pressure the discharges became less and less diffuse and their convexity towards each other diminished until, when a certain gas pressure was reached, it disappeared. At this point the discharges were very little diffuse and when allowed to pass through the reservoir simultaneously they remained rectilinear, but somewhat unsteady, oscillating quite appreciably about their rectilinear paths through the reservoir,

but the oscillations were always in the plane common to their rectilinear paths.

The pressure was still increased by turning the stopcock once around and allowing some more air to get in. The discharges became still less diffuse along their path through the reservoir and when allowed to pass one at a time they were quite steady and rectilinear. Both being allowed to pass through the reservoir simultaneously they were appreciably concave toward each other, but the concave arcs were in the plane passing through their shortest path in the reservoir. There was evidently a repulsive force acting between the discharges. This repulsive force increased continually with the increase of pressure in the vacuum, but with the increase of the force the steadiness of the discharges along their paths through the reservoir when they were both passing simultaneously gradually diminished. Fig. 3 (Plate XII) is a photograph of the discharges when taking place simultaneously in a vacuum in which the repulsive force just described was moderate. Fig. 2 is a photograph of the same discharges, but when taking place one at a time. Fig. 2 indicates that there is a repulsion between the discharge and the nearest wall of the reservoir, but this repulsion is very small in comparison to the repulsion acting between the streamers, when they take place simultaneously, as fig. 3 indicates. The photographs were taken by very short (1 to 1½ second) exposure, so strong is the luminosity of these discharges. They were taken when the repulsion was moderate, because when the repulsion is very strong the discharges oscillate very rapidly, so that they could not be well photographed with the apparatus employed. When the repulsion was so strong as to cause the streamers to curve way out and from time to time strike the nearest wall of the reservoir, the vibrations became very violent every time the streamers struck against the walls. They rebounded against the walls just as if they were luminous vibrating strings.

At this pressure in the vacuum it was very difficult to start the discharge and I had to strain the alternating machine and the induction coil to their utmost to make the start.* But when once started the discharge continues without any interruption even if the potential at the tinfoils is lowered 15 to 20 per cent.

The rate at which the temperature of these discharges increased with the increase of pressure in the vacuum seems to be much more rapid than the increase of the pressure; (the impressed *e. m. f.*, of course has to be increased with the pressure) and with the increase of the temperature the luminosity

* A gentle touch of the apparatus with a conductor will sometimes start the discharge at once when all other means of making this start fail.

of the discharge increased also. With the increase of luminosity the color of the discharge changed from the pink color, which is the characteristic color of the ordinary Geissler tube discharges through rarefied air, to a color which inclined more and more toward the white. With the increase of the pressure the diffuseness of the discharge disappeared, but instead of the diffuse pink color there appeared a beautiful green phosphorescent light which filled the whole reservoir. This phosphorescent light is so strong, that even an almost instantaneous exposure is sufficient to give it time to act upon the sensitive plate, as appears from the photographs in figs. 2 and 3. At some future date I shall describe experiments which seem to be a strong proof that phosphorescence produced by electrical discharges depends on the temperature and only in so far on quantity of the discharge and on the vacuum, as the temperature of the discharge depends on them. The investigations of Crookes, Goldstein, and others lead to the conclusion that a high vacuum with its cathode rays is most favorable if not indispensable to the development of strong phosphorescence. In my experiments a good vacuum (of about 2^{mm}) gave no phosphorescence whatever, whereas a poor vacuum (even with as high a pressure as 100^{mm}) gave very strong phosphorescence, and that too not only in places where the discharge struck the walls of the vessel but also in places which were far away from the discharge. Presently I shall describe an experiment which shows that the gas as well as the glass becomes strongly phosphorescent. My observations cannot, therefore, be well reconciled to those of Crookes, Goldstein, etc., unless the cathode rays be supposed to be very thin and very hot discharge filaments. I have several experimental facts which speak in favor of this hypothesis, but a discussion of them would lead me beyond the limits of this paper.

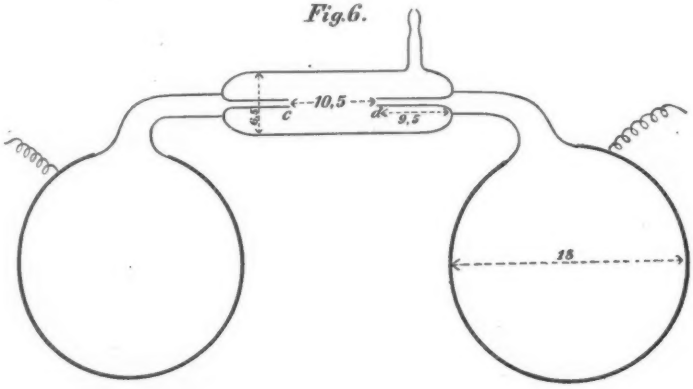
I find that some astrophysicists assume the existence of a repulsive force acting between the streamers of the solar corona; it was the peculiar behavior of the corona-like vacuum discharges which, in addition to other phenomena that came under my observation, forced me to assume that repulsive forces must be active between the filaments of these discharges, although at that time I was perfectly ignorant of the details of the various electrical theories of the solar corona. The streamers of these discharges are very unsteady and very much split up when the vacuum is poor. A photograph of a discharge of this kind is given fig. 4. As the vacuum improves the corona-like discharges become a great deal steadier, less torn up and quite diffuse, but never uniformly distributed over the whole spherical electrode. Fig. 5, represents the photograph of a discharge in the vacuum of about 20^{mm} pres-

sure. These photographs belong to my collection of photographs of corona-like vacuum discharges, an account of which I expect to give at some future time.

The question arose then, naturally, what is the cause of this repulsion? Electrostatic action suggested itself first, of course. But various observations which I made during my investigations on vacuum discharges made me favor another view, the view namely that the repulsive force between vacuum discharge streamers is due to a strain in the vacuum produced by the peculiar distribution of the gas pressure resulting from the peculiar distribution of temperature. If this view is correct then there should be no action between two vacuum streamers passing in two separated vacua. This suggested the following experiment:

Investigate the action of two discharge streamers upon each other when two separate discharge reservoirs are employed. Fig. 6, represents the apparatus (with its dimensions in cm.

Fig. 6.



marked), containing one of the reservoirs, two of which were placed side by side in the experiment. The bore of the capillary tubes *e*, *c*, *d*, *f*, was about 1·5^{mm}. The bulbs AB were coated with tinfoil and the whole arrangement was the same as in the experiments with the apparatus given in fig. 1. The two apparatus communicated with each other by means of a stopcock, so that the pressure was the same in each. The discharge in one apparatus did not influence the discharge in the other, no matter what the pressure was, up to the limit at which I could still obtain a discharge, which was about 60^{mm}. From this I conclude that the repulsion which I observed in the previous experiments was probably not due to electrostatic

action. The probability of the correctness of the other view is therefore considerably strengthened.

The apparatus for this experiment was constructed with two other objects in view, which ought to be mentioned here.

1st. To locate the phosphorescence. In this I was quite successful. It surrounded the hottest parts of the discharge, and therefore it was most intense in the narrow parts of the apparatus. Within the reservoir it extended from *c* to *d* in form of something like an ellipsoid of revolution, with the extremities of its longest axis at *c* and *d*, and at times this ellipsoid did not fill out the reservoir at all, which proves that the phosphorescent light in this part of the apparatus is due to the phosphorescence of the rarefied air and not to the phosphorescence of the glass, although in the narrower parts of the apparatus where the hot discharge was very near the glass the glass was also phosphorescent.

2d. To study what I call the ramification of the discharge. As soon as the pressure reached a certain limit the luminosity in the bulbs (which at low pressures was more or less uniformly diffused throughout the bulbs) became streaked, and at still higher pressures the whole discharge in its path through the bulbs divided itself into a number of distinct streamers, the number of streamers diminishing with the increase of pressure; given pressures produced invariably the same number of streamers. In this experiment I did not succeed in reducing the number of these streamers to less than two. The streamers rotated more or less uniformly in one direction or the other. The angular velocity of rotation seemed to increase considerably with the current of the discharge.

An exhausted glass bulb without electrodes when brought into the vicinity of these discharges emits a faint yellowish light which looks very much like the light of some forms of the aurora borealis. The bulb seems to remain perfectly cool. Lack of time and facilities have prevented me from determining the spectrum of this cold glow.

My thanks are due to Professors W. P. Trowbridge and J. K. Rees for the interest which they took in my work; also to Mr. Mann, of the Astronomical Observatory, for the very valuable service which he rendered to me in photographing these discharges.

I hope to continue this work with improved facilities as soon as time will permit.

Department of Electrical Engineering, Columbia College, February 28th, 1892.

ART. XXXIII.—*On a Melilite-bearing Rock (Alnoite) from Ste. Anne de Bellevue near Montreal, Canada;* by FRANK D. ADAMS.

AT the extreme southwest corner of the Island of Montreal and about twenty miles from the city of the same name, is the village of Ste. Anne, sometimes called Ste. Anne de Bellevue to distinguish it from a number of other places of the same name in the Province of Quebec. Here both the Grand Trunk and Canadian Pacific Railways cross the Ottawa river on bridges but a few yards apart, while under these and directly in front of the village is a short canal constructed to avoid the rapids which impede navigation at this point. Owing to the difficulty of navigating the Ottawa below this canal during times of very low water, it was decided to remove a ridge of rock in the river bed opposite the lower end of the village of Ste. Anne, and in this way to open up communication with a deeper channel on the opposite side of the river. In the summer of 1877 accordingly the Dominion Government put down cofferdams and having laid the bed of the river bare at this point blasted out the obstruction.

While this work was in progress, the locality was visited by Dr. B. J. Harrington, at that time connected with the Geological Survey of Canada, who found the bed of the river to be composed of well bedded sandstones and conglomerates of Potsdam age dipping to the south at an angle of 3½ to 4 degrees, cut through by a nearly vertical dike three feet thick and running N. 20° W. At one point a branch was observed running off from the larger dike. Much of the rock was entirely decomposed but a number of comparatively fresh specimens were obtained and notes on the mode of occurrence of the dike were published by Dr. Harrington in the Report of the Geological Survey of Canada for 1877–78, page 39 G, and also in the Canadian Naturalist, vol. ix, p. 253.

The rock however was fine grained and for the most part much decomposed, so that its true character was not recognized until the discovery by Törnebohm in 1882 of a melilite-bearing rock which he termed a melilite basalt* on the Island of Alnö in Sweden, which rock in hand specimens so closely resembled that from Ste. Anne, that Prof. Rosenbusch of Heidelberg to whom a specimen of the latter had been given was led to carefully reëxamine the sections of it for melilite. One or two crystals of this mineral found in one of the sec-

*A. E. Törnebohm: Melilitbasalt från Alnö, Geol. Fören. i. Stockholm Förh., 1882, p. 240.

tions served to indicate the relationship of the rock although in this particular specimen the melilite had been almost entirely destroyed by decomposition. This rock was therefore in the last edition of Prof. Rosenbusch "Massigen Gesteine," page 809, classed with that from Alnö as Alnoite, a dike rock corresponding to melilite basalt among the effusive rocks. As a new occurrence of a rare and curious rock it seemed worthy of careful study, the more so as it is, so far as I am aware, the first melilite rock that has been found on this continent.

The locality has therefore been revisited and a number of specimens of the fresh rock obtained from several large blocks which were thrown out on the slopes of the cribwork defining the channel. The dike itself of course cannot be seen, as it lies in the bed of the river and is now under several feet of water and but little fresh material can be obtained even from the blocks, as these are for the most part much decomposed. The strike of the dike would carry it through the village of Ste. Anne, but although the Potsdam sandstone is exposed in a number of places in the village no trace of the dike could be found, nor could any similar rock be found elsewhere in the vicinity.

The rock has a fine grained grayish-black groundmass through which are usually distributed large phenocrysts of biotite, olivine generally of a bright red color but sometimes green and black pyroxene. These are generally plentiful and sometimes so abundant as to constitute the greater part of the rock, giving it a very striking appearance. Some of the rock is almost free from these phenocrysts and consists of the fine grained groundmass alone, which in such cases is almost invariably much decomposed. It was impossible to ascertain whether this variety of the rock is confined to any particular part of the dike. The phenocrysts sometimes measure as much as 4 or 5 centimeters across but are generally somewhat smaller, $2\frac{1}{2}$ centimeters being the usual size. The biotites are frequently arranged in a rudely parallel position coinciding, as in the Swedish rock, with the direction of the walls of the dike, thus giving the rock a sort of schistose structure in this direction. The groundmass, which can only be studied properly in thin sections of the freshest material, is composed of smaller biotites, olivines and pyroxenes between which lies a still finer grained aggregate made up of individuals of melilite and little pyroxene spicules, the relative proportions of the two minerals varying considerably in different parts of the rock. Magnetite often in little cubes and octahedra occurs somewhat abundantly in the groundmass as well as in the form of inclusions in almost all the other constituents of the rock. Pyrrho-

tite is also present in small amount and can be separated from the powdered rock by means of a magnet. Apatite as well as perowskite, which is so constantly associated with melilite, is found in small amount in all the sections, while a little nepheline is probably present intimately associated with the melilite. Although some thirty-five thin sections have been prepared and carefully studied, no feldspar could be detected as a constituent of the rock. Curious angular fragments of a rather coarsely crystalline rock, composed in some cases almost entirely of plagioclase and in other cases of a granite or gneiss are not uncommon as inclusions. These are bounded by curious little contact zones and are evidently fragments of wall rock which have been brought up by the molten rock probably from the underlying Laurentian. Cavities, partially or completely filled with secondary minerals are also of frequent occurrence. The specific gravity of three average specimens of the rock was found to be as follows: 3·020, 3·013, 2·955.

For an analysis of the rock I am indebted to Mr. P. H. Le Rossignol of this University. In order to obtain as far as possible an average, a large number of fragments were broken from a series of the freshest hand specimens, and having been reduced to powder the whole was carefully mixed together and a portion taken for analysis. The results of the analysis of this Alnoite from Ste. Anne are given under I below, while under II the analysis of the melilite basalt from Hochbohl is reproduced from Prof. Stelzner's paper* for purposes of comparison. No analysis of the rock from Alnö has as yet been published.

	I.	II.
SiO_2	35·91	33·89
TiO_2	0·23	0·64
Al_2O_3	11·51	9·93
Fe_2O_3	2·35	15·63
FeO	5·38	----
CaO	13·57	15·19
MgO	17·54	16·14
K_2O	2·87	----
Na_2O	1·75	2·86
P_2O_5	not det.	1·41
CO_2	9·40	1·41
H_2O		2·90
	100·51	100·00

The large amount of water and carbonic acid present in the rock shows that even the freshest specimens have undergone

*"Ueber Melilith und Melilithbasalte," Neues Jahrbuch für Mineralogie, etc., 1882, Beil. Bd. II, 398.

very considerable alteration. The comparatively large percentage of potash in the Canadian rock is probably derived principally from the biotite which is present in large amount, while the Hochbohl basalt is nearly free from it. This biotite which is of a rich brown color occurs in individuals which although occasionally presenting a good crystalline form are usually irregular in shape. The basal sections are black or nearly so between crossed nicols and in convergent light show a cross, the arms of which separate somewhat when the section is revolved, indicating that the mineral is biaxial with a small axial angle. The lateral sections show the usual eminent basal cleavage with parallel extinction and a strong pleochroism, pale yellow sometimes nearly colorless, to deep yellowish brown. When a percussion figure is obtained and the optical orientation of the mica studied it is found to be different from that of ordinary biotite and like the mica in the Alnö rock,* to belong to Tschermak's first series. It is therefore anomite.

Around the biotite phenocrysts a narrow zone somewhat deeper in color but similarly orientated is often seen. It is distinguished from the inner portion of the crystal, not only by its color, but frequently also by the presence of minute inclusions, for the most part little pyroxenes like those of the groundmass, which are wanting in the inner portion. This zone is sharply defined against the inner portion and is frequently seen to build out the more or less rounded core into a more perfect crystalline form. The outer edge, although frequently minutely serrated, displays crystalline outlines. There has evidently been, first a separation of biotite in large phenocrysts, followed by a partial re-absorption and then a second crystallization of biotite, occurring partly in the form of zones about the remnants of the biotites of the first generation and partly as smaller individuals both in the form of phenocrysts and in the ground mass. The biotite of the first generation is lighter in color and free from pyroxene inclusions, while these occur abundantly in that of the second generation.

Olivine.—In the hand specimens the mineral is sometimes pale green but more frequently of a beautiful bright red color. It is usually well crystallized, especially the smaller phenocrysts and is traversed by a multitude of irregular cracks in addition to the lines of imperfect cleavage. When examined in thin sections by reflected light the color of the red olivine crystals is seen to be due to the presence of irregular wavy lines of ferric oxide of a brilliant red or orange color. That the ferric oxide, however, is present in but small amount is seen from the accompanying analysis I, of this red olivine by

* F. Eichstädt: "Anomit från Ålnö, Vesternorrlands län," Geol. Fören. i, Stockholm Förh., 1884, No. 87, 194.

Prof. B. J. Harrington.* An analysis of the olivine from the Hochbohl Melilite Basalt, II, made by Mr. Meyer is reproduced from Prof. Stelzner's paper for comparison. The olivine from the Ste. Anne rock is seen to be a variety much richer in magnesia and poorer in iron than that of the rock from Hochbohl.

	I.	II.
SiO_2	38·560	41·90
MgO	44·369	28·48
FeO	12·649	29·16
Fe_2O_3	1·361	----
MnO	0·112	----
H_2O (ign.)	2·914	----
	99·965	99·54

The oxide of manganese contains a little oxide of cobalt. The olivine is remarkable however chiefly on account of the very peculiar character of the alteration which it has undergone. The product of this alteration is in some cases the usual decomposition product serpentine, but in other cases a highly ferriferous magnesite (Breunerite). These minerals sometimes occur separately, one olivine crystal being altered to serpentine while another near it is changed to magnesite but they are more usually found together as alteration products of the same olivine individual. The serpentine is green in color and is developed as usual along cracks and cleavage lines often extending inward from these, a perfect pseudomorph being finally produced. The magnesite occurs as a cryptocrystalline or very fine microcrystalline aggregate also working its way into the olivine along the cracks and cleavage lines or else eating its way in from the exterior of the crystal in masses having a peculiar scalloped outline. When developed as a narrow edging along cracks, it is seen to have a somewhat fibrous structure in a direction at right angles to the crack but the fibers are not arranged in a sufficiently parallel position to afford a dominant extinction. When occurring in larger grains the fibrous structure is not seen and the mineral becomes compact, often indicating however by its structure the position of the cracks in the olivine along which it was developed, just as serpentine usually does. Occasionally it shows a very imperfect spherulitic structure. It is transparent to translucent in thin sections, and although the individuals are minute is seen to have a high index of refraction and strong double refraction. By reflected light it has a dull white or yellowish white color.

*B. J. Harrington: "On the occurrence of Olivine in Canada," Report of the Geological Survey of Canada, 1877–78, page 39 G.

When thin sections are treated with cold diluted hydrochloric acid the magnesite remains unaltered, even cold concentrated hydrochloric acid does not dissolve it. When however the acid is warmed the greater number of the magnesite pseudomorphs are completely dissolved, others however, are only partially dissolved, or are dissolved only in certain places, owing apparently to the fact that in these cases the alteration into magnesite is not yet complete or is complete only in certain parts of the pseudomorph. By carefully searching a large number of hand specimens it was found to be possible to obtain a sufficient amount of the magnesite apparently quite pure, to enable its blowpipe characters to be determined and also for chemical analysis. Before the blowpipe it decrepitates somewhat and blackens but does not fuse even on the thin edges. After ignition it shows an alkaline reaction with turmeric paper and in its other blowpipe reactions, which it is unnecessary here to detail, agrees with magnesite. A small fragment placed in cold concentrated hydrochloric acid gives off a few minute bubbles but goes into solution only with extreme slowness. The specific gravity of four little fragments was taken by the aid of Thoulet's solution and a Westphal's balance and was found to range from 3·062 to 3·072 at 19·5° C.

The following analysis of the apparently pure material referred to above, dried in vacuo over sulphuric acid, was kindly made for me by Dr. B. J. Harrington.

MgO	32·68
CaO	0·93
FeO	16·24
CO_2	44·61
SiO_2	3·38
H_2O	2·13
	99·97

When the combinations are calculated the percentages of the carbonates are found to be as follows:

$MgCO_3$	64·83
$FeCO_3$	26·16
$CaCO_3$	1·66

This leaves an excess of 1·81 p. c. of magnesia, which is probably present as a hydrous silicate. The silica, which remains behind in a flocculent condition when the mineral is treated with hot hydrochloric acid, is probably derived in part from a little serpentine present as an impurity.

When both serpentine and magnesite are present as alteration products in the same olivine individual their boundaries against one another are sharply defined and the two minerals do not occur mixed together. The magnesite seems to have been formed before the serpentine, as it frequently occupies the outer part of the crystal while the inner portion is altered to serpentine. In these cases the alteration to magnesite appears to have gone on to a certain point and then ceased, while the rest of the olivine was subsequently altered to serpentine in the usual manner. Two of these altered olivine crystals are represented in the accompanying figure (fig. 1). In one of them magnesite alone is present as a decomposition product, while the other is altered to magnesite and serpentine.

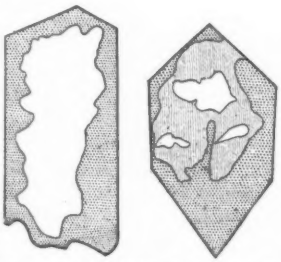


FIG. 1. Alteration of olivine to magnesite (stipple) and to magnesite and serpentine (vertical lines). The white spaces are unaltered olivine.

It is believed that this peculiar alteration of olivine has not been hitherto observed. A very similar if not identical alteration product, however, is seen in the olivine occurring in certain fine grained nepheline-bearing dykes from the Montreal mountain, and in Sagvandite* we probably have a somewhat similar alteration of bronzite to magnesite.

Pyroxene.—The pyroxene which is one of the most abundant constituents in the rock is also in many respects remarkable. Two varieties are present, one forming the large phenocrysts and the other occurring very abundantly in the groundmass. The phenocrysts which, as mentioned above, are often very large, are usually well crystallized but sometimes have more or less rounded forms. The mineral is fresh and unaltered even when the other constituents have undergone considerable decomposition even where cavities filled with secondary minerals have eaten their way into its substance the pyroxene around their border is quite fresh. When crystallized, basal sections present eight sided forms showing a development of both prismatic and pinacoidal forms, with good cleavage parallel to the former and extinction parallel to the latter. It is monoclinic and the maximum extinction observed in the zone of the orthopinacoid and clinopinacoid was 42.° It is colorless and never shows more than mere traces of pleochroism, it has however a strong dispersion of the bisectrices so that when a thin section is revolved between crossed nicols until the point of maxi-

*H. Rosenbusch: "Ueber den Sagvandite," Neues Jahrbuch für Mineralogie, etc., 1884, p. 195.

mum darkness is reached a slight revolution of the stage in one direction will cause the pyroxene to assume a light brown tint, while a movement of a few degrees in the reverse direction will cause it to appear of a grayish-blue color, the section never becoming black and the contrast of color often being very marked.

This same dispersion is seen in the pyroxene occurring in the alnoite from Alnö, in the melilite basalt from Hochbohl, as well as in many of the nepheline bearing rocks found in the vicinity of Montreal. It is believed to be a variety containing a considerable amount of titanic acid but it has not as yet been analyzed. Almost every one of the larger phenocrysts has a narrow border or zone, well defined against the inner core, but differing from it both in color and angle of extinction. This zone, which can sometimes be seen even in hand specimens, is light brown in color in the thin sections and probably has the same composition as the pyroxene occurring in the groundmass and forming the smallest phenocrysts, which have no core, seeing that it resembles this in optical properties. This zone has a larger extinction than the inner portion, the difference frequently amounting to 16° and even more. The crystalline outline of the pyroxene phenocrysts is frequently seen to be much more perfect than those of the inner core, the latter often having a distinctly rounded form while the former present true crystalline outlines. The zone moreover, although sharply defined against the inner core along a curved line frequently has a somewhat serrated outer limit showing like the biotite many little projections running out into the groundmass. The same phenomenon is noted by Törnebohm in the pyroxene in the alnoite from Alnö. It would thus seem that the pyroxene like the biotite had first been crystallized out as large phenocrysts, that these had been partially reabsorbed giving to them rounded contours and that subsequently pyroxene had again been crystallized out of the magma, forming the zones about these larger phenocrysts, tending to restore to them their original crystalline forms and also at the same time forming the smallest phenocrysts and all the little pyroxene crystals in the groundmass which, as above mentioned, resemble in character that of the zones.

The pyroxene occurring in the groundmass takes the form of swarms of minute elongated often acicular crystals of a light brown color. In some sections they constitute the greater part of the groundmass. They have a high index of refraction, are not pleochroic and sometimes occur twinned parallel to $\infty P\bar{\infty}$. They occur very frequently penetrating the biotite and other constituents of the rock and are often embedded in them.

Melilite.—This mineral which gives to the rock its distinctive character is well characterized and is quite abundant in some of the sections, while in others it occurs more sparingly. It is found almost invaribly as flat tabular crystals shortened in the direction of the vertical axis. Basal sections of these crystals have rectangular or eight sided outlines and are isotropic, while prismatic sections present lath shaped forms which between crossed nicols show parallel extinction. Sometimes however the crystals are not so flattened but have the form of short stout prisms while frequently they are irregular in shape. The individuals ordinarily range in size from ·016^{mm} to ·046^{mm} in thickness and from ·07^{mm} to ·17^{mm} in length. The largest of a considerable number which were measured was ·46^{mm} by ·057^{mm}, this however is unusually large. Törnebohm says that in the rock from Alnö the melilite crystals are seldom over ·1^{mm} in length. The mineral is usually colorless but often has a slight but distinct yellowish tint. It has a much higher index of refraction than nepheline but the double refraction is weak, the polarization colors in good sections varying from very dull blue to bluish gray. In the lath shaped sections a basal cleavage can often be distinctly seen and in such cases the extinction is of course parallel to it, as it is parallel to the sides of the lath shaped sections when the cleavage is not seen. At right angles to this cleavage and therefore parallel to the vertical axis, what Stelzner has called "peg structure," which is so characteristic of melilite is often excellently developed. This cleavage with the "peg structure" at right angles to it, when well seen indicates with certainty the orientation of the melilite individual and the study of a large number of such grains in slides prepared from several hand specimens, with the aid of a gypsum film giving between crossed nicols red of the first order, shows that in all cases the vertical axis is the axis of greatest elasticity, that is to say that the mineral is negative. When both minerals are developed in crystals giving lath shaped sections, the gypsum plate affords a ready means of distinguishing melilite, from nepheline, seeing that in the latter mineral the longer axis of the oblong sections is parallel to the vertical axis.

In basal sections the "peg structure" appears as little dots. The melilite is often traversed by irregular cracks in addition to the basal cleavage. The accompanying figure (fig. 2) drawn from one of the thin sections of the rock, shows the mineral with better crystalline outlines than it usually possesses, associated with biotite, magnetite and apatite and surrounded by a mass of decomposition products consisting of the most part of calcite.

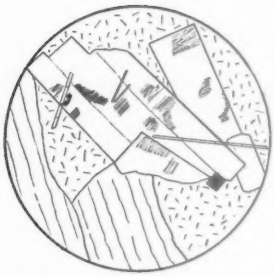


FIG. 2. Melilite showing "peg structure" associated with biotite, magnetite and apatite.

An attempt was made to separate the melilite from the groundmass of one of the freshest and most coarse grained specimens by means of heavy solutions but it was found to be impossible to do so, the average melilite individuals being too small and the mineral being impure on account of the presence of inclusions and decomposition products. The melilite is well seen only in sections of the fresh rock, when the rock is decomposed to any considerable extent the mineral is replaced by alteration products and no longer easily recognizable. When a portion of the groundmass is finely powdered and boiled for a short time with hydrochloric acid a slight gelatinization can be observed sufficient to cause the powder to adhere to the sides of the tube but not sufficient to make a jelly. When a section is treated with hydrochloric acid and then with fuchsine the melilite is seen to be distinctly stained.

Nepheline.—In addition to the melilite and in much smaller amount, there is in many sections a clear colorless mineral occurring in little corners in the groundmass which resembles the melilite, but seems to have a much lower index of refraction and never shows "peg structure." This is probably a little nepheline, but after carefully studying a large number of thin sections no positive proof on this point could be obtained as the mineral has not a good crystalline form. The other constituents of the rock exhibit no peculiarities deserving of further mention.

The order of crystallization of the principal constituents is as follows: First, the magnetite, then olivine, biotite and pyroxene of the first generation in the order named, then probably another generation of olivine, followed certainly by a second generation of pyroxene and biotite while the melilite has crystallized last of all.

The secondary minerals filling the cavities before mentioned are quartz and calcite. The former mineral is represented for the most part by microcrystalline and cryptocrystalline varieties. The calcite occasionally shows excellent pleochroism, yellow and colorless. A little opal and a small quantity of some zeolite are probably also present in a few cases. These are not primary but true secondary cavities eaten out of the various constituents of the rock.

This alnoite from Ste. Anne differs from the original alnoite from Alnö, in containing much more olivine and in being free from plagioclase, a mineral which can be frequently observed in sections of the Alnö rock. Otherwise they resemble one another very closely. Although there is no way of ascertaining the age of this dike it is probably connected with the great volcanic center at Montreal which constitutes the elevation known as Mount Royal, from which the city takes its name. This is formed of a theralite, cut through by a later eruption of elæolite syenite, both rocks breaking through and altering the Trenton limestone of the vicinity, the whole being traversed by several series of dikes, tinguaites, bostonites and other rocks to which a definite name cannot at present be given but which probably originally held some melilite although they are now as a general rule much altered. Dr. Harrington has been for several years collecting material and data for an accurate description of the whole complex and we hope before long to have the work sufficiently advanced for publication. The present paper may be considered as a first contribution toward an accurate knowledge of these rocks.

McGill University, Montreal.

ART. XXXIV.—*On an Azure-blue Pyroxenic Rock from the Middle Gila, New Mexico;* by GEORGE P. MERRILL and R. L. PACKARD.

AMONG a lot of ores and other materials donated to the Museum some months ago by Prof. J. H. Huntington then at Silver City, New Mexico, was a hand specimen of a finely saccharoidal rock of a beautiful light azure-blue color with spots of serpentine, and which was stated to have come from a point on the Gila River some 40 miles west of that city. The striking beauty and color of the rock at once excited our interest, and arrangements were made for analysis and microscopic study. Meanwhile business called Mr. Merrill to Silver City, and while there he took pains to visit the locality and learn for himself the source and geologic character of the rock. The results of our combined investigations are given in the following notes.

In the field the rock was found to occur in sporadic nodular masses of rarely 100 pounds weight, imbedded in a granular crystalline serpentinous limestone which in the form of a nar-

row, nearly vertical bed, enclosed between granitic and basic eruptives, forms a continuation of the peculiar banded serpentinous rock commercially known as *ricolite* and which has been put upon the market as an ornamental stone.

Under the microscope, in thin sections, the rock is seen to consist wholly of short and stout colorless granular pyroxenes interspersed with occasional small areas of interstitial calcite. None of the pyroxenes show idiomorphic forms but the structure is eminently granular, the individual crystals varying in size up to 1 mm. in greatest length. Cleavage is very poorly developed, but an occasional basal section shows a nearly rectangular parting and gives a biaxial interference figure with the optic axis lying in the plane of symmetry. The blue color so striking in the hand specimens is naturally quite lacking in the section, nor is there evident pleochroism. As is often the case with rocks of this class a serpentinous alteration has set in giving rise to a beautiful compact oil-yellow and greenish serpentine with the liberation of abundant free calcite, but so far as observed no chalcedonic or other form of free silica. The absence of secondary silica in alterations of this kind, has been noted by Mr. Merrill in previous papers,* as in marked contrast with serpentines resulting from the alteration of rocks of the peridotite group which are nearly always traversed by strings and veins of chalcedony.

A piece of the blue rock free from serpentine was pulverized, treated with warm hydrochloric acid to remove calcite and then boiled in an alkaline carbonate. The analysis gave:

		Molecular ratio.
SiO_2	54·30	·905
MgO	18·33	·458
FeO	1·11	·015
CaO	25·00	·446
	98·74	

This reduces to the formula, $CaMgSi_2O_6$, which is that of malacolite.

The striking blue color of the mineral would appear to be due wholly to iron protoxide as careful tests fail to indicate the presence of other metallic substances nor is the color changed by the action of strong acids or moderate heat.

National Museum, Feb., 1892.

* On the Serpentine of Montville, New Jersey. Proc. United States National Museum, 1888, p. 105: Notes on the Serpentinous Rocks of Essex Co., New York, etc., ibid. vol. xii, 1889, p. 595; and On the Ophiolite of Thurman, Warren Co., New York, this Journal, vol. xxxvii, March, 1889, p. 189.

ART. XXXV.—*On the Correlation of Moraines with Raised Beaches of Lake Erie;* by FRANK LEVERETT.

THE observations recorded in this paper, and its accompanying maps, were made for the United States Geological Survey during the field seasons of 1889, 1890 and 1891, and are here published by permission, in advance of the official report. In the prosecution of the work I have had the constant supervision of Pres. T. C. Chamberlin to whose guidance in the study of the glacial phenomena I am greatly indebted. I have also received valuable suggestions from Mr. G. K. Gilbert which have been of service in the study of the beach lines.

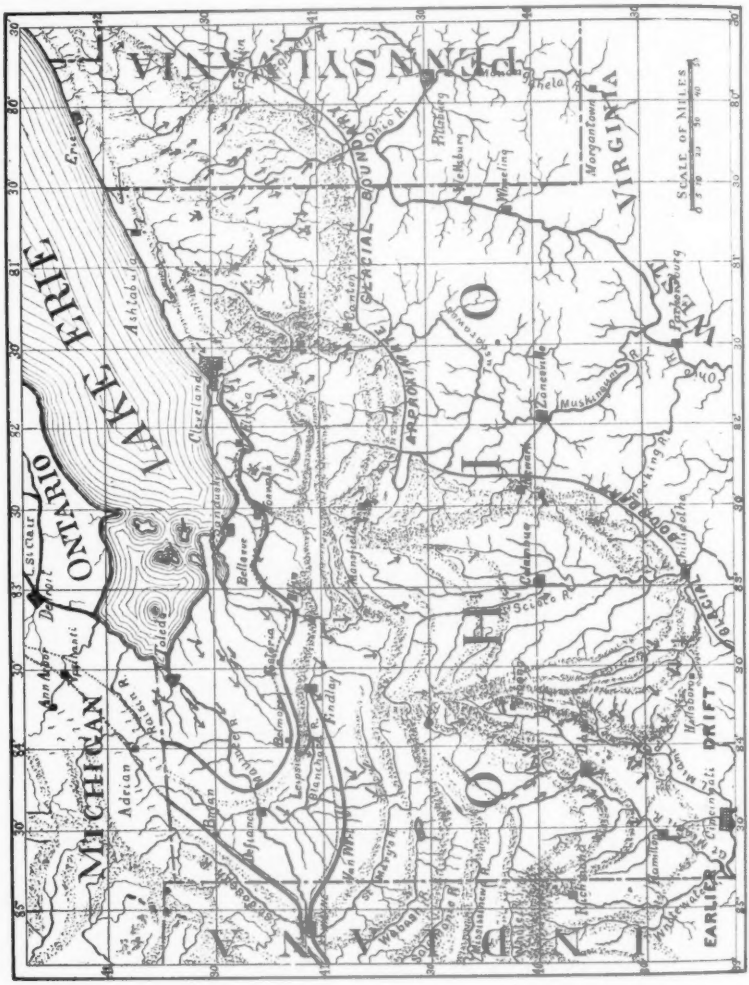
Before entering upon the discussion of the beaches and their correlative moraines a few remarks are necessary as to the evidences of lakes or inland seas in the drift covered portions of Ohio, south of the well defined beach lines, during the closing stages of glaciation. In early publications on the drift of Ohio, and also of adjacent States, glacial phenomena such as osars, kames, moraines of gravelly constitution, and overwash gravel aprons bordering moraines, were appealed to in support of a hypothesis of submergence of the land during the closing stages of the glacial epoch, and a recent publication in this Journal includes with the beaches of Michigan, certain moraines and their overwash gravel aprons.* That such phenomena do not demand a submergence is now quite generally conceded by glacialists, and in the district in question they have been found to be independent of lacustrine conditions.

Throughout the part of Ohio along and south of the continental watershed, and in northern Indiana and southern Michigan where these deposits of assorted drift occur, the moraine-headed terraces, which follow the principal streams, show clearly that the land had such an altitude at the time the ice was forming its moraines as to afford good drainage for the waters issuing from the ice margin.

Instead of a depression of the land in the later episodes of the drift deposition in the eastern Mississippi basin, such as is taught by the early writers, there was a greater altitude than in the earlier stages This subject has been thoroughly considered by Pres. Chamberlin in a paper before the A. A. A. S. at the recent meeting in Washington, and his paper is already published in full in the American Geologist.†

* High Level Shores in the region of the Great Lakes and their Deformation, J. W. Spencer, this Journal, March, 1891, pp. 209–10.

† The altitude of the eastern and central portions of the United States during the Glacial Period, T. C. Chamberlin, Am. Geol., Nov., 1891.


LAKE ERIE
ONTARIO
MICHIGAN
INDIANA
OHIO
VIRGINIA
PENNSYLVANIA
Cleveland
Akron
Toledo
Ann Arbor
Detroit
Adrian
Bryan
Defiance
Bellevue
Sandusky
Norwalk
Mansfield
Zanesville
Columbus
Springfield
Dayton
Cincinnati
Wheeling
Morgantown
Fairmont
Parkersburg
Huntington
Portsmouth
Ironton
Chillicothe
Lancaster
Newark
Coshocton
Canton
Massillon
Wooster
Findlay
Fostoria
Tiffin
Bucyrus
Marion
Delaware
Hamilton
Richmond
Connersville
Greenville
Piqua
Sidney
Lima
Van Wert
Celina
Kenton
Bowling Green
Fremont
Sandusky
Port Clinton
Sandusky Bay
Maumee Bay
Maumee R.
Sandusky R.
Scioto R.
Muskingum R.
Hocking R.
Kanawha R.
Ohio R.
Wabash R.
Miami R.
Whitewater R.
Great Miami R.
Little Miami R.
Scioto Trail

It is a common belief that when the ice-sheet had made its final retreat to the slope north of the continental watershed in Ohio, even though the altitude remained high, lakes would be formed in front of it which would stand at a higher level than the Ft. Wayne outlet, and discharge through passes in the water-shed at altitudes as great as 350 to 400 feet above Lake Erie. Dr. Newberry speaks of these passes as water-gaps and waste weirs.* Prof. E. W. Claypole has indorsed this view and carried the idea further by outlining on a map several theoretical lakes on the north slope of the watershed.† The studies of the past season do not, however, support this mapping. The actual outline of the ice-margin at that stage in its retreat is far from coincident with Prof. Claypole's theoretical outline. It will be seen from the moraines shown on the accompanying map (fig. 1) that as soon as the ice had withdrawn from the watershed in northern Ohio it had withdrawn so far in northwestern Ohio that there was adequate outlet for the discharge of its waters past Ft. Wayne down to the Wabash river. This outlet being much lower than the passes on the watershed eastward from there, the necessity is removed for the existence of extensive lakes at levels sufficiently high to discharge through these passes. It is true that quite heavy deposits of silt occur in the Cuyahoga valley and slight deposits in the valleys which lead to Lake Erie west from that valley, but they are all of earlier date than the latest of the ice advances. While examining the Cuyahoga valley I was accompanied by Prof. Claypole who recognized, with me, as *glacial* the deposits that cap the silts along the valley. The glacial deposits referred to consist of till along the greater part of the valley, but west of Akron they consist of gravel. The till is aggregated in places into morainic ridges and knolls, and the outer of these ridges has an overwash gravel apron leading from it across the watershed to the Tuscarawas valley, and that too where there are deposits of silt 100–200 feet or more in thickness below both the till and the gravel. This is a clear indication of the presence of land ice in these valleys subsequent to the deposition of the silts. The probable age and conditions of deposition of these silts constitute a question of much interest, but beyond the scope of this paper, since it does not pertain to the closing stages of glaciation.

The result of investigation has been therefore to reduce the noteworthy lakes connected with the closing stages of glaciation in Ohio to the one bounded by the beach lines which were recognized by the Ohio Geological Survey.

* Geol. of Ohio, vol. i, pp. 43–45; vol. ii, pp. 46–48, 51–53.

† Lake Age in Ohio, E. W. Claypole, Trans. Edinb. Geol. Soc., 1887.

Some years ago Mr. Gilbert discovered that several of the raised beaches of Lake Erie do not completely encircle that body of water but terminate in a successive series from higher to lower in passing eastward from northern Ohio to southwestern New York. The results of his study are unpublished, but through his kindness I have been supplied with the principal data. In explanation of the termination of these beaches, Mr. Gilbert has entertained the theory that they represent successive positions of the ice-front in its northeastward retreat across the Lake Erie basin, but has held that the complete verification of this theory depends upon the occurrence of moraines which are demonstrable correlatives of the beaches. Such moraines have now been discovered and traced into connection with the eastern ends of the three beaches which terminate in Ohio. The glacial phenomena in the vicinity of the termini of the lower beaches (in southwestern New York) have not yet received attention.

The characteristics and limitations of the several stages of the lake whose presence is known by these raised beaches, are but partially determined, my investigations being confined to its south shore. The data already obtained are, however, believed to be adequate to show that the higher beaches are of the same age as certain moraines, and to warrant the conclusion that the higher stages of the lake occurred as a result of the occupancy of the eastern portion of the basin by the retreating ice-sheet.

The facts I wish to present are naturally grouped under three heads: (I) The Van Wert or upper beach and its correlative moraine the Blanchard ridge: (II) The Leipsic or second beach and its correlative moraine: (III) The Belmore or third beach and its correlative moraine. The names here adopted are those suggested by Prof. N. H. Winchell.*

I. The Van Wert or Upper Beach and its Correlative Moraine.

(*a*) *The Van Wert or Upper Beach.*—The distribution of this beach in Ohio and Indiana is well shown in maps published many years ago by Mr. Gilbert.†

From Mr. Gilbert's description in the Geology of Ohio, (pp. 549–550) we take the following account of this beach and the outlet of the lake.

"The Maumee valley is well adapted to the display of these beaches since on its easy slopes they are so broadly separated that they can be traced without confusion, and in its soft drift

* Proc. Am. Assoc. Adv. Sci., 1872, pp. 171–179. Geol. of Ohio, vol. ii, p. 56.
† This Journal, May, 1871, p. 341. Geol. of Ohio, vol. i, 1873, p. 540.

they were inevitably modeled at every stage of the water's lingering. Four shore lines above the present are distinguished. The first marks a water level at 220 feet, the second at 195 feet, and the third at 170 feet above the Lake, while the fourth records a slow descent from 90 feet to 65 or 60.

West and north of the first beach—that is, above it—the Erie clay lies undisturbed, with the rolling surface it received from the unequal heaping of the iceberg loads of which it is largely composed. Upon such a surface the result of shore action could not escape notice, and the evidence of its absence is not merely negative in its character. I feel warranted in saying that from the northwest corner of the State to the upper beach (a horizontal distance of twenty miles with a fall of 200 feet), the waters of the glacial sea did not linger in their descent.

The Upper Beach consists in this region of a single bold ridge of sand, pursuing a remarkably straight course in a northeast and southwest direction, and crossing portions of Defiance, Williams and Fulton counties. It passes just west of Hicksville and Bryan; while Williams Centre, West Unity and Fayette are built upon it. When Lake Erie stood at this level it was merged at the north with Lake Huron. Its southwest shore crossed Hancock, Putnam, Allen and Van Wert counties, and stretched northwest, in Indiana, nearly to Fort Wayne. The northwestern shore line, leaving Ohio near the south line of Defiance county, is likewise continued in Indiana, and the two converge at New Haven, six miles east of Fort Wayne. They do not, however, unite, but instead, become parallel, and are continued as the sides of a broad water-course through which the great Lake basin then discharged its surplus waters southwestward into the valley of the Wabash river, and thence to the Mississippi."

In so far as it deals with *phenomena* the above description is graphic and valuable for our purpose, but the references to glacial seas and iceberg drift the author himself would doubtless throw out were he to revise his paper. Whether or not this glacial lake was merged with Lake Huron at the time this beach was forming is, I think, undetermined, since the moraine that lies between it and Lake Erie has not, so far as I am aware, been traced through southwestern Michigan. It is quite possible that the ice-sheet occupied the Lake Huron basin at the time as it is known to have occupied the Lake Erie basin. In that case the two basins would not have been united by lake water to the extent suggested by Mr. Gilbert.

Tracing the Van Wert ridge westward to the outlet from its eastern terminus near Findlay, we find it passing through the following villages and cities in the order named: Findlay,

Benton Ridge, Webster, Pandora, Columbus Grove, Alnora, Delphos, Middlepoint and Van Wert, Ohio, and through Zulu P. O., Indiana, to the outlet at New Haven. The north shore, according to Mr. Gilbert's tracing, leads northeast from New Haven, Indiana, and passes just west of Hicksville and Bryan, Ohio. Dr. J. W. Spencer identifies it in Michigan at Adrian, Ypsilanti and Berville.* It is not improbable, however, that this beach terminates before reaching Ypsilanti and if so correlation should be made there with the second beach.

Mr. Gilbert's estimate of the height of this beach is based upon its altitude where crossed by the L. S. & M. S. R. R. near Bryan,† where it is about 220 feet. The altitude is slightly lower along the south shore than at Bryan, as shown by several independent railway surveys. It is evident, however, from the variations displayed by these surveys that accurate leveling and a critical study of the beach with reference to its usual stage of water will be required, before any conclusions can be drawn as to differential crust movement between Findlay and Fort Wayne. The beach here apparently stands about 210 feet above Lake Erie. In the table given below, the lower altitudes are slightly below the usual stage of water. In Michigan there is, according to Dr. Spencer, a marked northward differential uplift between Ypsilanti and Berville.

*Table of altitudes along the Van Wert Ridge.**

* The altitude above Lake Erie is 573 feet above tide.

Stations.	Altitude Ab. Lake Erie.	Remarks.
Findlay, O., L. E. & W. R. R.	209 feet.	Vol. vi, Geol. of Ohio.
" " "	205 "	Dict. of Altitudes.
Pandora, O., P. A. & W. R. R.	202 "	Taken from profile.
Columbus Grove, O. "	202 "	" " "
Alnora. " "	203 "	" " "
Delphos, " "	214 "	" " "
" Miami canal.	211 "	Dict. of Altitudes.
" P. F. W. & C. R. R.	208 "	Surface of Miami canal.
Middlepoint. O. "	211 "	Vol. vi, Geol. of Ohio.
Van Wert, " "	211 "	Dict. of Altitudes.
New Haven, Ind. (beach S. of),	205 "	Bar. from N. Y. C. & St. L. R. R.
Bryan, Ohio, (ridge W. of),	220 "	From profile L. S. & M. S. R. R.
Adrian, Mich.	216 "	Am. Journ. Sci. (Spencer.)
Ypsilanti, " (terrace)	211 "	" " "
Berville, "	244 "	" " "

The Van Wert ridge so far as I have examined it consists in the main of a deposit of sandy gravel though for considerable distances it presents only a wave-cut bench free from gravels. It is not a strong bench, its usual height being 3–5 feet and its breadth but 10–12 rods. Occasionally, however,

* This Journal, March, 1891, p. 209. † This Journal, May, 1871, p. 343.

opposite the place where streams tributary to the lake had their *debouchure*, it is much larger, standing 12–15 feet above the plains either side of it and having a breadth of 20–40 rods or even more.

The beach apparently terminates at a cemetery near the south bank of Blanchard river in the western part of Findlay. It is here in the midst of a plain that rises gradually toward the north, the east and the south, so that the lake at its eastern terminus was a mere point and its waters quite shallow. The beach is about as well developed at its eastern terminus as it is, on the average, west from there, so there is no difficulty in tracing it. Along the north side of Blanchard river, west from Findlay, no well defined beach of corresponding age with the Van Wert ridge appears. It is evident that the plain between the river and the Blanchard moraine was submerged, for it is coated in places with sand and gravel, and much of it is as low as that between the river and beach on the south. Sand also sets in on the outer (south) slope of the Blanchard moraine, a few miles west from Findlay, and reaches altitudes as great as on the beach south of the river, but I could trace no shore lines.

The strength of the beach at its eastern terminus raises the suspicion that the ice may have been more remote when the principal work was done on the beach and afterwards re-advanced to the position indicated by the moraine, for the water between the beach and the moraine constituted a narrow pointed bay and as a rule the beach following the side of such a bay is not as strong as the beach facing a broad sheet of water. However no conclusive evidence of such a re-advance of the ice-sheet was discovered. The phenomena along the moraine as shown below seem to indicate that the ice-sheet overhung it while the lake was still occupying the Van Wert beach and thus prevented the waves of the glacial lake from making their impress on the moraine.

(*b*) *The Blanchard Moraine.*—The Blanchard is the latest moraine of the series in Ohio that can be traced around the western end of Lake Erie. Its course may be seen on the accompanying map (fig. 1). Westward from Findlay the moraine is on the whole a less conspicuous feature than eastward from that city, but may be easily traced in a curving course northwestward to the Maumee just below Defiance, and thence north into Michigan. The portion of it west from Findlay was discovered and mapped by Mr. Gilbert more than twenty years ago.* It is therefore one of the earliest recognized moraines on this continent.

* This Journal, May, 1871, pp. 339–342.

The moraine rises and falls in its course across Ohio showing but little dependence upon levels, though there is usually a slight southward curve at the lowlands and a reëntrant or northward curve on the highlands crossed by it. The following table of altitudes will illustrate its great range. It embraces the portion between the Maumee river and the interlobate tract in Geauga county, Ohio.

Table of Altitudes along the Blanchard Moraine.

Stations.	Altitude A. T.	Remarks.
Near Defiance,	730 feet.	Wabash R. R. profile.
Pleasant Bend,	742 "	T. St. L. & K. C. profile.
Summit S. of Leipsic,	780–85 feet.	Bar. from W. Leipsic.
Summit S. of McComb,	795–800 "	" " McComb.
Summit N. of Findlay,	840–850 "	" " Findlay.
Alvada,	850 "	Geol. of Ohio, vol. vi.
Sandusky river bluff,	830 "	Bar. from Tiffin.
Near Rockaway,	900 "	Bar. from Attica.
Attica, B. & O. R. R.,	963 "	Dict. of Altitudes.
Near Chicago Junction,	950 "	Bar. from Chicago Junct.
Near New London,	1050 "	" " New London.
2 mi. N. E. of Troy (Nova P. O.),	1182 "	Prel. Surv. P. A. & W. R. R.
Lodi,	910–925 "	Bar. from station.
Chatham (1 mi. N. of Center),	1120 "	Bar. from Litchfield Sta.
Near Medina,	1100 "	" " P. A. & W. R.R. Sta.
Near Remson's Corners,	1200 "	" " Medina.
Cuyahoga river bluff,	950 "	" " Peninsula.
Eastern Cuyahoga and western Geauga Counties,	1000–1250 "	" " various stations.

From the interlobate tract in Geauga county westward to a few miles beyond the meridian of Findlay this moraine, in its topography and general appearance, is like other moraines south of it, consisting of a broadly ridged and slightly undulating tract of till standing 20–40 feet or more above the plain south of it, and having a breadth of 1½–3 miles. Near the meridian referred to it assumes a very different appearance having a knob and basin topography of subdued type in which knolls of conical form rise abruptly 5–10 feet and cover an acre or less each, and among which are sharp-basins occupying usually but a small fraction of an acre each, though frequently several feet in depth. The crest of the moraine is no longer well defined though it continues to be a watershed between tributaries of the Maumee all the way to that stream near Defiance. On the accompanying map (fig. 2) an attempt is made to represent this change in the topography.

The structure presents as marked a change as the topography. Instead of a uniform deposit of till at the surface there is a variety of formations remarkable for the abruptness of their alternations. In one knoll a fine sand may occur

while its neighbors are composed of clay, or a portion of a knoll may be sand and the remainder clay, the whole being molded together into a symmetrical knoll like the gravel and till in ordinary kames. A few knolls contain gravel but as a rule pebbles are rare and no surface bowlders or large pebbles are observed. The clays are very calcareous and abound in nodules in nearly every exposure. This variable structure characterizes the superficial portion of the ridge only. At a depth of about 15 feet stony till sets in which does not differ perceptibly from that in the portion of the moraine further east which was formed above the level of the lake water.

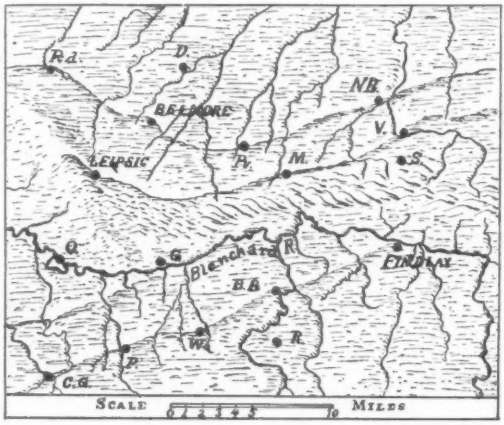


FIG. 2. *Map of a portion of Hancock, Putnam, Henry and Wood Counties, Ohio, showing the junction of the Van Wert beach and its correlative, the Blanchard moraine.*

Explanation of Map.—An attempt is made to represent the topography graphically, the beaches being indicated by steps or benches cut in the plain, and the moraine by curved lines representing its billowy and irregular surface. The letters indicate villages and cities as follows: (Rd.) Ridgeland; (D) Deshler; (N B.) North Baltimore; (V) Van Buren; (S) Stuartville; (M) McComb; (Pv.) Pickensville; (O) Ottawa; (G) Gilboa; (CG) Columbus Grove; (P) Pandora (Pendleton); (W) Webster; (R) Rawson; (BR) Benton Ridge.

Such is the character of the moraine for a distance of ten or twelve miles. About three miles northwest from Leipsic the Leipsic or second beach crosses the moraine and from there northwestward the moraine has a comparatively smooth surface the result of wave action subsequent to the retreat of the ice.

The portion of the moraine of especial interest is the knob and basin tract, above described. If my interpretation be cor-

rect this owes its peculiar topography and structure to the presence of lake water beneath the ice-margin. This portion of the moraine has an altitude but slightly below the level of the Van Wert beach, consequently the water was shallow and incapable of buoying up the ice-sheet and producing icebergs. The result was what might be anticipated under such conditions of deposition, a variable structure produced by the motion of waters under the edge of the melting ice-sheet, and an uneven surface molded by the inequalities of its base and margin. It may be suggested that the moraine received its sandy deposits from a lake that covered it after the ice had retreated. It seems improbable, however, that such was the case, (1) because the sandy deposits are not in the form of a beach nor in any way connected with a well defined beach, but are in sharp knolls similar to the clay knolls of the moraine; (2) because the sand in places graduates into clay of glacial origin showing contemporaneous deposition with it; (3) because the basins and depressions are so sharp and of such a form and arrangement as to forbid the idea that the wave action had been long exerted on them; (4) the portion of the moraine northwestward from where the Leipsic beach crosses affords a clear illustration of the effect of an open lake on the moraine, its surface being smooth and its sand either a uniform coating or aggregated into forms clearly referable to wave or wind action. It is fortunate that the lake in its later stages fell short a few feet of reaching its earlier maximum stage and thus left unmodified a portion of what appears to be a lake-deposited moraine. So far as I am aware no cases of a moraine demonstrably formed in lake water have been reported from other parts of the glaciated district, but it is not improbable that other instances will be found when attention is directed more closely to this subject, if they have not already been observed by other students. It is quite probable that in portions of this moraine farther north, there will be found other places similar to that just described. My studies were not carried north of the Putnam and Henry County line.

Summing up the phenomena of this district it appears (1) that the Van Wert ridge terminates near Findlay, Ohio, and that east from there the Blanchard moraine is its correlative; (2) that the Blanchard moraine from near the meridian of Findlay northwestward, was deposited in lake water. The beach as well as the morainic phenomena therefore support the hypothesis that the lake bounded by the Van Wert beach was of *glacial* age.

II. The Leipsic or Second Beach and its Correlative Moraine.

(*a*) *The Leipsic or Second Beach.*—From the meridian of Findlay eastward to its eastern terminus at North Linndale there is no beach higher than the Leipsic, but from that meridian west this beach stands second in the series. Careful search between Findlay and North Linndale not only failed to reveal a beach outside of this one, but convinced me that no effective wave action was there exerted, there being present in large numbers the small knolls of till and other irregularities of contour produced by the glacier which would have been rendered obscure and perhaps effaced had there been wave action on it for any prolonged period. Moreover, no deposits of sand, gravel, or silt were observed that could be referred to lake action.

Tracing the beach from its eastern terminus westward it leads us through the following cities and towns in the order named: North Linndale, Rockport, Fields Corners, La Porte, Carlisle Center, South Amherst, Axtell, Berlin Heights, east part of Norwalk, Pontiac, Bellevue, Lowell, Tiffin, Bascom, Fostoria, Van Buren, McComb, Leipsic, and West Leipsic. From McComb to West Leipsic the lake washed the north slope of the Blanchard moraine. About three miles northwest of West Leipsic the beach crosses the moraine and swings south following nearly the southwest or outer border of the moraine to the Blanchard river at Crawfis college, just below Gilboa. From Blanchard river it is reported to pass south of west leaving Ottawa about three miles to the north, but I have not traced it beyond that stream. This beach is probably the correlative of Mr. Gilbert's second beach that passes through Hicksville and Bryan, Ohio.

Table of Altitudes along the Leipsic Beach.

Stations.	Altitude Ab. L. Erie.		Remarks.
North Linndale, C. C. C. & St. L. R. R.	196	feet.	Notes from Chief Engineer.
Rockport, L. S. & M. S. R. R.	200	"	From profile.
2 miles E. of Shawville.	200	"	L. S. & M. S. profile.
Carlisle Center.	204	"	Geol. of Ohio, Vol. II.
Huron County Infirmary.	203·5	"	Notes from County Surveyor.
Pontiac, B. & O. R. R.	190	"	Top of beach, 195 feet.
2–4 miles E. of Bellevue.	208–12	"	L. S. & M. S. profile.
2 miles W. of Bellevue.	208	"	" " "
Tiffin.	210	"	Bar. from B. & O. R. R.
Bascom, B. & O. R. R.	209	"	Top of beach 215 feet.
Fostoria, L. E. & W. R. R.	209	"	Geol. of Ohio, Vol. VI.
Van Buren, T. & S. R. R.	209	"	" " " "
McComb, N. Y. C. & St. L. R. R.	195	"	Notes from Chief Engineer.
West Leipsic, " " "	192–5	"	" " " "
Crawfis College, F. Ft. W. & W. R. R.	197	"	" " " "
Hicksville, B. & O. R. R.	188	"	Dict. of Altitudes.
Bryan, L. S. & M. S. R. R.	191	"	" "

The principal embayments in the ancient shore are at Black, Huron and Sandusky rivers. At Vermillion river there was scarcely any embayment. These embayments do not owe their existence to different rates of erosion of the shore under wave action, but were probably produced by the ice-sheet previous to the occupancy by the lake, the effect of the ice-sheet being to broaden the mouths of old valleys which it entered. The lake nowhere cut back its shore a mile, and usually but a few rods while it occupied this beach, as may be determined by a restoration of the original slope on which it was carved.

It is not improbable that the terrace noted by Dr. Spencer at Ypsilanti, Michigan, should be correlated with the second beach instead of with the Van Wert ridge, for the next lower beach observed by him near that city is below the level of the Leipsic beach, the altitude being but 161 feet above Lake Erie or about the altitude of the third or Belmore beach of northwestern Ohio. If the Ypsilanti terrace proves to be the correlative of the second beach there is a differential uplift of 20 feet between Bryan and Ypsilanti, a distance of about 50 miles.

Certain altitudes in the above table will no doubt raise the question as to the possibility of correlating this beach with the Van Wert ridge. From Van Buren to Bellevue it has apparently as great an average altitude as the Van Wert ridge. Since the stations included between these towns have altitudes obtained from several independent surveys and show essential harmony it is unlikely that they contain great errors or exaggerations of the altitude of the beach. A beach formed subsequent to the retreat of the ice, as the Leipsic beach was, cannot be correlated with one formed while the ice-sheet still occupied the Blanchard moraine. Reasons have already been given for considering the Van Wert ridge the correlative of the Blanchard moraine, and to my mind they hold good even though portions of the Leipsic beach be as high as the Van Wert ridge. The Leipsic beach certainly fluctuates in altitude. I have followed it continuously from Van Buren to McComb and made certain that it represents but a single stage of the lake; yet there is a difference of 14 feet in the altitude of these stations (seven miles apart). The altitudes being obtained by independent surveys it is possible that a portion of the difference may be due to their not checking in their results, but probably only a small portion. A study of the profiles of the L. S. & M. S. R. R. reveals the fact that the beach is at least 10 feet higher at Bellevue than it is between Cleveland and Elyria, and its survey is carefully checked since it comes down nearly to lake level both at Sandusky and Cleveland. It is, therefore, well established that in the vicinity of Bellevue the beach has suffered a slight differential elevation. This elevation may

cover the whole interval from Bellevue to Van Buren where the table shows its highest altitude to be.*

The general appearance of this beach is much like that of the Van Wert, though it is on the whole somewhat stronger. Throughout much of its course it stands 6–8 feet above the plain north of it, and in places 15–20 feet. In the vicinity of Vermillion river and thence west nearly to Norwalk, and again in the cape-like projection in the vicinity of Bellevue it is quite sandy, but as a rule it contains but little sand. In pits at Bascom, a village between Tiffin and Fostoria where the beach attains the extraordinary height of 215 feet above Lake Erie, the gravel contains a remarkably large percentage of angular or but slightly worn pebbles, and elsewhere along the beach the rounding of the pebbles is slight compared with that in the present beach of the lake. This beach, in common with the upper and third beaches, contains much poorly assorted material and where the deeper parts of the beach contain well assorted gravel, there is usually a capping of clayey gravel two feet or more in thickness in which bowlders are sometimes imbedded. The beaches were apparently short lived and rapidly formed otherwise the pebbles would be more water worn and the clayey ingredients less conspicuous. It is not improbable that throughout much of the year the borders of the lake were fringed with floe ice and the presence of bowlders in the beaches may be due to this agency.

The view that the waters of the lake at the time it occupied these raised beaches were cold, seems sustained by the extreme rarity of the remains of Molluscan life in its beaches. Careful observation and inquiry while on the ground failed to bring to light any evidence of such life, but after leaving the field I was told by a farmer who formerly lived on the upper beach a few miles east from Van Wert that he had seen "clam shells" in its sands. This observation needs verification, however, by some competent student before much weight can be attached to it, for untrained observers often call the brachiopod shells of the quarries "clam shells." These beaches contain such shells that were washed up from the glacial drift, which includes material derived from the neighboring rock formations. Since the absence or scarcity of fossils is not always due to the

*This portion of the beach characterized by high altitudes, is on the crest and eastern slope of the "Cincinnati axis," which leads from the Ohio river near Cincinnati northerly across the western part of Lake Erie, (Geol. of Ohio, vol. vi, map opposite p. 48.) It will be a question of some interest to determine whether or not this coincidence is due to recent uplift of this axis. I have not sufficiently full data on the altitudes of lower beaches than the Leipsic to enable me to determine whether or not they also show a rise in passing over the Cincinnati arch. In case they do it is to be presumed that the arch has been slightly uplifted since the beaches were formed.

original absence of life but often to the lack of conditions for preservation, this evidence should be taken with caution.

Horns of elk and deer have been obtained from the Leipsic beach in the railway gravel pit near Crawfis college between Gilboa and Ottawa. They were imbedded in undisturbed beach gravels at a depth of eight or nine feet below the surface, and are therefore as old as the beach itself.

As previously stated, the Leipsic beach has its terminus at North Linndale. The beach here connects with the western end of a moraine. By reference to the accompanying map (fig. 3)

Fig. 3. *Map of Cleveland and vicinity showing the junction of the Leipsic and Belmore beaches with their correlative moraines.*

Explanation of Map.—The beaches are represented by a series of benches or steps cut in the bluffs and plains. The Leipsic beach comes to the bluff of Big creek at North Linndale (NL) the Belmore beach near Brighton (B). The terraces in East Cleveland are to be seen between Newburg (N) and the Garfield Monument (GM). Two lower beaches are indicated. Their exact position in the city of Cleveland was not mapped but is probably within a mile of the position indicated in the map. These lower beaches alone occur east from Euclid. The moraines are indicated by curved lines representing the billowy and uneven surface which they present. The letters indicate villages as follows: (W) Willoughby; (GM) Garfield Monument; (Rl) Randall; (N) Newburg; (B) Brighton; (NL) North Linndale; (R) Rockport; (Ba) Berea.

it will be seen that the beach just east of Rockport swings from a course north of east to a southeasterly course, and is there made up of a series of ridges of nearly uniform height which are united at the curving portion of the ridge but diverge into distinct ridges toward the southeast so that their ends are spread out over a space of nearly one-half mile. The outer ridge comes to Big creek bluff in North Linndale.

There is outside of these beach ridges a peculiar ridge which appears to be a compromise between a beach and a moraine. At its western end, near the inner bend of a tributary of Big creek, a mile or so west of North Linndale, it is composed of gravel and resembles in every way the beaches just north of it, but upon tracing it eastward the gravel changes to till, giving it the appearance of a low glacial ridge. This low till ridge may be traced through North Linndale to the bluff of Big creek near the bend of that stream, and upon crossing the creek we find a much larger ridge of till, one worthy the name moraine. This large ridge is separated from the eastern end of the beach proper by the narrow valley of Big creek, one fourth mile or less in width. I was unable to find beach gravel along the inner (north) slope of the morainic ridge farther east than the terminus of the beach ridge, but this inner border district is very flat and its clays contain few pebbles compared with the clays of the moraine. These features apparently indicate that the lake water covered the tract north of the moraine, either while the ice overhung it or subsequently.

From Newburg northward to the Garfield Monument there are two terraces along the east bluff of the Cuyahoga, which may possibly be correlated with the Leipsic and Belmore beaches. It is however doubtful if the correlation of the upper terrace with the Leipsic beach is legitimate, since the terrace stands slightly higher than the beach at its eastern terminus in North Linndale, being 210–220 feet above Lake Erie as determined by Dr. Newberry,* while the Leipsic beach is but 196 feet. Dr. Newberry recognized the difficulty of making this correlation and suggested that the lower terrace which stands 165–170 feet above Lake Erie, is the correlative of the upper beach at North Linndale, "since a terrace is cut by shore waves somewhat below the water level, while on a gently inclined surface of loose material the waves raise a beach above the water" (p. 182). My examination of the upper terrace failed to disclose beach deposits on it or other decisive evidence that it was occupied by the lake, but the decision as to whether or not it is a lake terrace should be left to one more familiar than I with the various phases such terraces may present. Dr. Newberry suggests that the upper terrace may find its correlative west of the Cuyahoga in some undiscovered shore line south of the Leipsic beach, but since, as previously stated, the districts south of the beach do not afford distinct evidence of any such shore line, this view does

* Geol. of Ohio, vol. i, pp. 181–182.

not seem to be sustained. I am inclined to correlate the lower of the two terraces, with the Belmore beach, since the altitude is not too great for that stage of the lake, and to leave the question open as to whether or not the lake extended back to the upper terrace at the time it was forming the Leipsic beach. That the lake at the time of the Leipsic beach did not extend farther east than Cleveland has been determined by Mr. Gilbert who has given the beaches of the eastern end of the Erie basin careful study.

(*b*) *The Correlative Moraine of the Leipsic Beach.*—This moraine as indicated above is traceable no farther west than North Linndale. Both north and west from there the surface, aside from the low beaches, is a monotonous plain with scarcely any undulation. The disappearance of the moraine at the point where the beach appears, leaves little room for doubt that the ice-sheet here terminated in a lake and that the beach is of glacial age. The portion of the moraine west of the Cuyahoga does not show evidence that it was deposited in lake water, on the contrary its structure so far as exposed opposes such a theory of deposition, the mass of the ridge being ordinary till without capping of sand or other water deposits. But since the descent is rapid toward the Lake Erie basin from the junction of the beach and moraine, there was sufficient depth of water to cause the ice-sheet to break up into bergs at its margin instead of resting upon the lake bottom and forming such a moraine as it did in the western Erie basin northward from the junction of the Van Wert beach and Blanchard moraine.

Tracing the moraine eastward we find it passing just south of the village of Brighton near which it is interrupted by the Cuyahoga valley. It reappears on the east side of the river in Newburg and is traceable from there eastward through Randall and Warrensville to the Chagrin river below Chagrin Falls. Its farther course may be seen on the general map (fig. 1). West of the Cuyahoga it is a single gently undulating ridge about 80 rods in width and 20–30 feet in height. East of the river it consists of many short ridges and conical swells 10–25 feet in height and has a width of 1–2 miles or more. In places there is a well defined crest but as a rule the crest is wanting.

The range of altitude is considerable. West of the Cuyahoga the moraine stands about 800 feet A. T. East of the river it rises from 800 feet at Newburg to 1050 feet at Randall (only six miles distant), and ranges up and down 200–250 feet in eastern Cuyahoga and Geauga counties in crossing ridges and valleys, its highest points being about 1250 feet A. T.

The thickness of drift as shown by its relief above border districts is only 20–30 feet, but spread out as it is over a width of 1–2 miles it represents a vast accumulation compared with that of the correlative beach. The moraine is composed principally of till, though in places it has gravelly knolls (kames). Pockets of gravel and sand occur in the till and beds of assorted material are occasionally interstratified with it. In short, the moraine in its topography, range in altitude, bulk and constitution, is so different from the beach that the two formations cannot be confused, and yet there seems to be no question that the moraine of the eastern Erie basin has, in the western Erie basin, a beach for its correlative.

III. The Belmore, or Third Beach, and its Correlative Moraine.

(*a*) *The Belmore Beach.*—This beach was not traced continuously from Belmore to its eastern terminus, but standing as it does third in the series, and having an altitude about 30 feet below the Leipsic beach, there is but little possibility of error in correlation. From the Cuyahoga river westward it resembles the Leipsic beach so closely in size, form and structure that further description seems unnecessary. From Cleveland nearly to Tiffin it is seldom more than two miles from the Leipsic beach, and much of the way but a mile or less. From near Tiffin to Belmore it is 3–5 miles north of the Leipsic beach. Between Belmore and the Michigan line its course is directly away from the Leipsic beach, northwesterly, through Ridgeland, New Bavaria and Ayersville to the Maumee river at Independence, as indicated on Mr. Gilbert's map.*

Beyond this stream its course is east of north into Michigan. In Michigan it is correlated by Dr. Spencer with the Ridgeway beach of that State.†

Careful leveling will be necessary to determine the amount and direction of deformation, if any has occurred along the Ohio portion of this beach, since it was formed. The few altitudes obtained show the beach to be between 160 and 170 feet above Lake Erie. The highest point known to me is at the crossing of the C. C. C. & St. L. railway between Cleveland and North Linndale where it is 170 feet, but there may be points further west equally high. Dr. Spencer's data indicate a northward rise in Michigan, the altitude east of Ypsilanti being 161 feet, at Berville 180 feet, and at Emmett 197 feet above Lake Erie.

This beach if my interpretation be correct is represented east of the Cuyahoga by the lower of the two terraces in the

* Geol. of Ohio, vol. i, p. 548. † This Journal, March, 1891, p. 207.

east part of Cleveland, previously mentioned, which stands about 165 feet above Lake Erie. From Cleveland eastward Mr. Gilbert has given the raised beaches of Lake Erie critical study and finds no beaches there that can be correlated with the Leipsic and Belmore beaches. Before discussing further the termination of this beach, it will be profitable to consider its correlative moraine.

(*b*) *Correlative Moraine of the Belmore Beach.*—There is along the south border of the Lake Erie basin from the eastern end of the lake, nearly to Cleveland, a well defined moraine which lies nowhere more than eight miles, and in places but two or three miles, from the present shore of the lake. It lies along the escarpment south of the lake, and occupies a belt a mile or more in width. Its inner border comes down to within 250–300 feet of the level of the lake, and is usually less than 100 feet above the highest of the raised beaches in that part of the lake basin. Its outer border varies greatly in altitude on account of the form of the escarpment along which it lies. In southwestern New York and northwestern Pennsylvania where the escarpment is abrupt it reaches altitudes nearly 1000 feet above Lake Erie, but in northeastern Ohio the outer border is but little above the inner. I have examined the moraine no farther east than Lake Chautauqua in southwestern New York. From Lake Chautauqua westward to Painesville, Ohio, some 30 miles east from Cleveland, the moraine exhibits considerable strength. It has a nearly continuous main ridge, on whose slopes and borders knolls are disposed in morainic fashion. From the vicinity of Painesville westward to its terminus the moraine is much weaker. It seldom has a well defined crest but consists of low knolls, isolated or in groups, among which are quite extensive nearly plane tracts. The moraine is traceable westward to Euclid, a small village about ten miles northeast from the center of Cleveland (see fig. 3). West from Euclid the old shores of the lake turn southward and cut off any continuation toward the west which the moraine may have had. The moraine is however so feeble at Euclid that it seems improbable that the ice-sheet extended much farther west at that time. This moraine along the shore of the lake basin is lateral rather than terminal to the ice-sheet, the terminal portion being in the midst of the lake basin. Judging from the feebleness of the moraine west of Painesville it is improbable that it has sufficient strength to be traceable on the lake charts across the lake bottom, and a moraine may not have been formed there, since the water was apparently of sufficient depth to break up the ice-sheet into bergs near its margin.

Parts of this moraine have been classed with the beaches by early writers.* This confusion appears to have arisen mainly from the imperfect knowledge of the phases of structure which a moraine may present, especially in its gravelly and sandy portions, though in one of the instances above cited a large till ridge is called a beach. In the profile section from Lake Erie to Grand river (Geol. of Ohio, vol. ii, p. 62) the southernmost of the four ridges, there shown, is this moraine. The highest beach is there about 150 feet above Lake Erie while the moraine is 260 feet. The beaches are narrow ridges only a few rods in width, while the moraine has a width of one-half mile or more. The beaches are composed of sand and assorted material, the moraine of till, with occasional developments of gravelly knolls. In places in Ashtabula county the moraine and beach are closely associated, and beach sand appears on the moraine, but through much of its course in Ashtabula county as well as elsewhere the moraine is quite distinct from the beach and free from such deposits. Sand occasionally caps the moraine in places where it was not encroached upon by the beach, and that too at higher altitudes than portions not thus coated. In such cases it may have been drifted back from the shore by the wind. Some of it may however have been deposited by waters attending the melting of the ice-sheet, and be similar in origin to kames, rather than to dunes or beaches.

The Belmore beach has not been traced into close connection with this moraine, but if we consider the lower terrace in East Cleveland its correlative, the gap is nearly filled. In my opinion there is no objection to this correlation since the height of the lower terrace is slightly below that of the portion of the Belmore beach immediately west of the Cuyahoga, being about 165 feet, while the beach at the crossing of the C. C. C. & St. L. R. R. is 170 feet above Lake Erie. It seems therefore that in this, as in the next older moraine, a moraine of the eastern Erie basin, has in the western Erie basin, a beach for its correlative.

In the earlier beaches there is no question that the Lake Erie basin has a southwesterly outlet into the Wabash river, their altitude being slightly above that of this outlet, and the beaches being open there, but the Belmore and later beaches are below that level and do not open toward the outlet. We must therefore look elsewhere for their outlet. It is evident that it was not along the present route, nor by the Mohawk valley, since the ice-sheet filled at this time the western portion

* Second Geol. Surv. Penn., Q_4, pp. 38, 39. Geol. of Ohio, vol. i, pp. 488–90, 518; vol. ii, pp. 60–63.

and perhaps the whole of the Ontario basin and the eastern Erie basin. The only outlet remaining is through the Lake Huron and Lake Michigan basins to the Chicago outlet. The distance to which the ice-sheet had retreated in the Lake Erie basin seems to warrant us in believing that the Huron and Michigan basins may have been so far cleared of ice as to afford an outlet in this direction, either around the north end of the Southern Peninsula or across it via Saginaw Bay and Grand river valley.

Summary and Conclusions.

From the data above presented it appears that Lake Erie in its earlier stages was but a small body of water, its size being conditioned by the position of the retreating ice-sheet and by the height of the western rim of the basin it occupied. It at first occupied only a portion of the district between the outlet and the western end of the present lake, the remainder of the basin, including the whole of the area of the present lake, being occupied by the ice-sheet. Its south and north shores were then at the Van Wert ridge, while its eastern border was at the Blanchard moraine.

By a recession of the ice-sheet northeastward to about the meridian of Cleveland, the lake became much expanded and its level was lowered a few feet, though the outlet still continued down the Wabash. Its north and south shores then occupied the second or Leipsic beach, while on the east the waves beat against the ice front. The ice-sheet itself seems to have broken into bergs at its margin, and to have formed no terminal moraine at that time though its lateral moraine is well developed.

A subsequent recession resulted in the lowering of the lake below the level of the Ft. Wayne outlet probably by opening a passage to the Chicago outlet for no other outlets were open to this lake at that time through the Huron and Michigan basins. The north and south shores of the lake were then occupying the Belmore beach, while the east shore was unrecorded because the waves beat against a vanishing sheet of ice, and the ice itself, as in the preceding stage seems to have failed to form a terminal moraine, though its lateral moraine is strong.

From the phenomena attending the replacement of the three beaches in Ohio by moraines we are led to suspect that two later beaches which die away in southwestern New York are there connected with moraines, and that similar moraines will be found to connect with the beaches of Lake Ontario, at

points where they disappear on its eastern and northern borders.

Differential uplift was slight in the western Erie basin compared with what it was in the eastern Erie basin and the Ontario, in Michigan, and on the Canadian shores of Lake Huron and Georgian Bay. The data at hand indicate that it amounts to scarcely more than ten feet in the whole area of the portion of the Erie basin west of Cleveland, and has therefore played an insignificant part in causing the three stages of the lake herein described.

The bulk of the moraines is many times that of the beach deposits, though no longer time was involved in their deposition. The ice-sheet was therefore a much more efficient transporting agency than the lake waves.

The extreme scarcity of evidence of life in these waters, though negative in its nature, and therefore to be taken with caution, is quite accordant with the theory deduced from the relation of the beaches to the moraines, viz: that the beaches are of glacial age.

Art. XXXVI.—*Magnesium as a Source of Light;* by Frederick J. Rogers, M.S.

[Contributions from the Physical Laboratory of Cornell University, No. 9].

I.

Quality of Magnesium Light.

The light produced by the combustion of magnesium is brilliantly white. It is whiter than the arc light and almost rivals sunlight itself. When the spectrum of the magnesium light is formed side by side with that of ordinary gaslight, the former is immediately seen to be relatively much stronger in the more refrangible rays. It gives a continuous spectrum, superimposed upon which are the ever present sodium lines D_1 D_2 and the magnesium lines b_1 b_2 b_4 as well as four or five oxide bands.

In the experiments to be described in the first part of this paper the brightness of magnesium light in different parts of its spectrum was compared with the corresponding components of gaslight from an Argand burner by means of the "horizontal slit" photometer.* This is a spectrophotometer movable along a photometer bar. It furnishes, side by side, spectra of the two sources of light to be compared, the two

* Described by Dr. E. L. Nichols, in Trans. Am. Inst. of E. E., vol. vii.

spectra being viewed in the usual manner by means of an observing telescope. The advantage of this form of spectrophotometer is that there is no polarizing device, equality of the particular portions of the spectra compared being obtained by movement along the photometer-bar.

The light to be studied was produced by the combustion of magnesium-ribbon $2\frac{1}{2}^{mm}$ wide, supplied at a uniform rate by means of clock-work. The light was very variable, a fact which greatly increased the difficulty of determining its quality. Even when a diaphragm with an opening of 2×5^{mm} was placed immediately in front of the burning ribbon this variation in intensity was quite marked. The best that could be done was to take the mean of a large number of observations. The comparison was made at eight points very nearly equidistant in the normal spectrum. Five sets of observations were made making in all fourteen readings for each of the eight points in the spectrum. Table I gives the ratios, magnesium light: gaslight, reduced to unity at the D line, as obtained by taking the mean of these five sets of observations.

TABLE I.

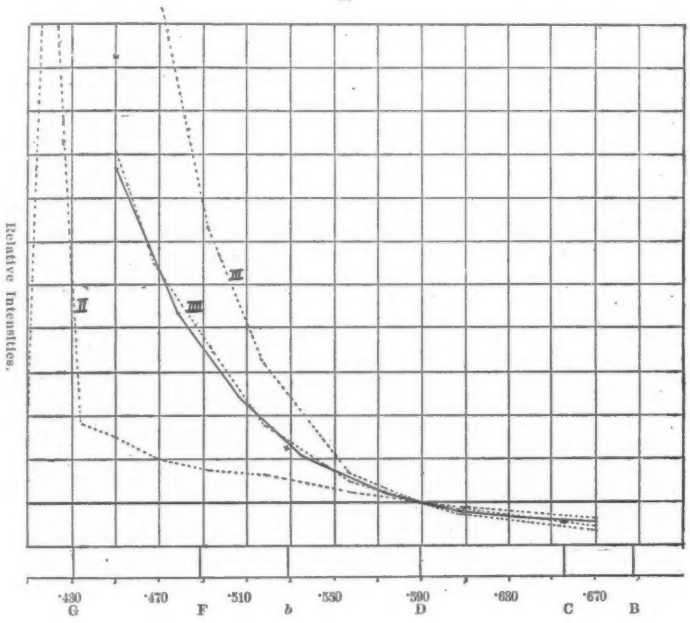
Wave-lengths.	Mg. light. / gaslight.	Wave-lengths.	Mg. light. / gaslight.
·450	8·77	·574	1·21
·479	5·33	·606	0·83
.506	3·43	·635	0·66
·536	2·07	·670	0·53

The full curve in fig. 1 represents graphically the relation between wave-lengths and relative intensity in the case of the magnesium light. The standard gaslight is arbitrarily taken to be unity in all parts of the spectrum. Curve II*, fig. 1, represents the relative intensity of the arc light for different wave-lengths as obtained by Dr. Nichols in 1888. Curves III and IV, fig. 1, represent the relative intensity of daylight as compared with the standard. III represents daylight from a cloudless sky and IV, daylight from a heavily clouded sky. In the latter case the cloudiness happened to be just sufficient to make daylight almost identical in character with the magnesium light. For these dotted curves the standard light was a sixteen candle power incandescent lamp which, however was found to give a light nearly identical in quality with the light from an Argand gas burner. The stars in the figure for $\lambda = ·656$, ·527, and ·450 represent the values for magnesium light obtained by Prof. Pickering in

* This Journal, vol. xxxvii, p. 100.

1879.* It will be seen that the results from Table I, are quite in accordance with those of that observer and sustain his statement that of all artificial illuminants the magnesium light approaches sunlight much more nearly than does any other.

1.



II.

Temperature of Burning Magnesium.

An important question in regard to the magnesium light is that of the temperature at which combustion takes place. Flame temperatures are not well known. Rossetti† has found 1350° for the hottest part of a Bunsen flame and 640° to 940° for a stearine candle flame. As I knew of no experimental data whatever on the subject of the temperature of burning magnesium, I attempted to measure it by means of the E. M. F. produced in a thermo-element composed of platinum and platinum-iridium, when the element was placed in the flame. A thermo-element of those materials had been previously cali-

* Proc. Am. Acad. of Arts and Sciences, 1879–80, p. 236.
† Annalen der Physik, Beiblätter, I, p. 615, II, p. 335.

brated* using as known temperatures the melting points of metals, for high temperatures,† silver 954°, gold 1035°, copper 1054°. As the melting point of copper is far below the temperatures to be measured it is necessary to prolong the calibration curve beyond the points determined by observation. But as this curve is almost exactly a straight line from 700° to 1050° it is probably safe to prolong it to, at least within 200° or 300° of the melting point of platinum.

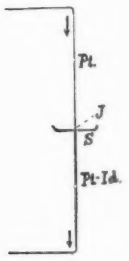
It was soon found that burning magnesium almost instantly destroyed the small platinum wire used (·01 inch diameter), apparently by some chemical action, as there was no evidence of fusion. To determine the temperature in the ordinary way, by noting the permanent deflection of a galvanometer needle when the thermo-junction was held in the magnesium flame, was clearly impossible. To obviate this difficulty several indirect methods were employed, in all of which the temperature of burning magnesium was determined by comparison with other flame temperatures.

The temperatures of the flames to be used as standards in this work, were determined by the writer by means of the E. M. F. produced by them in the above mentioned thermo-junction. These flames were air blast flame, Bunsen flame, luminous gas flame (Bunsen burner with the air holes closed) and candle flame. In all cases the object was to get the temperature of the hottest part of the flame. No galvanometer readings were taken, until by repeated trial, the deflection was as great as could be obtained. The final results of three sets of observations are given in Table II.

Three methods employed in the estimation of the temperature of combustion of magnesium are described below.

First method.—The wire of the thermo-element was passed through a small hole in a porcelain screen which protected the junction as shown in fig. 2. The platinum-iridium wire was then heated as closely as possible to the screen by the different flames, including the magnesium flame and the corresponding galvanometer "swings" were noted. Three determinations by this method are given in Table II.

2.

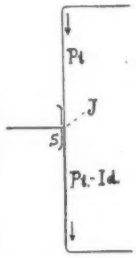


Second method.—It was found that after the platinum-iridium wire had been heated a short time by the magnesium-flame, a *negative* deflection of the galvanometer was obtained. An investigation proved that the burning magnesium formed a black compound with the wire and that this substance formed with the platinum-iridium a thermo-element whose

* By Mr. Ernest Merritt in the course of an investigation not yet published.
† "Physikalische-Chemische Tabellen." Landolt und Börnstein.

E. M. F. was negative, the E. M. F. in the original element being considered positive. To eliminate this accidental E. M. F., the thermo-junction was made in the form of a T as in fig. 3 and the projecting portion which passed through a porcelain screen was heated as before by the different flames. Two determinations by this method are given in Table II.

3.



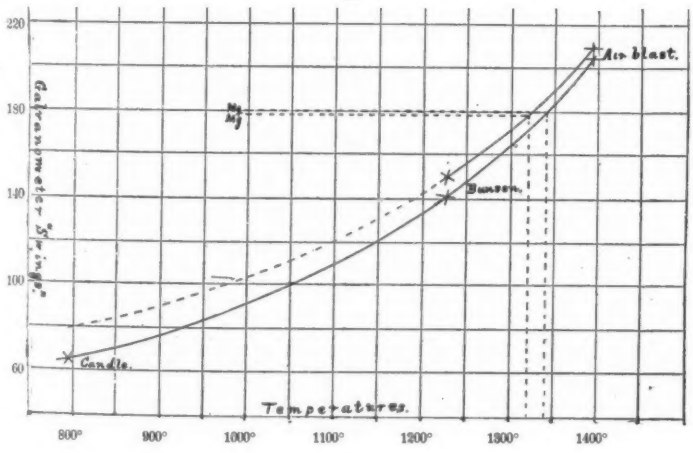
Third Method. — In this case a rather large bead of metal was formed at the junction. The junction was then *directly* heated by the different flames, last of all by the magnesium flame, and the galvanometer "swings" were noted as before. The thermo-element was not so quickly destroyed as before; nevertheless, only one reading for the magnesium flame could be obtained before making a new junction. Two determinations were made by this method.

TABLE II.

Candle flame.	Luminous gas-flame.	Bunsen flame.	Air blast flame.	Method.	Magnesium flame.	
827°	....	1227°	1398	First	1345°	1333°
					1375	
					1280	
765	992°	1233	1382	Second	1350	1342
					1333	
792	1018	1222	1404	Third	1320	1332
					1345	

The values for the flame temperature of magnesium, given above, were obtained by a graphic method which is illustrated

4.



in figure 4. The previously determined temperatures of the other flames were plotted as abscissæ and the corresponding galvanometer "swings" as ordinates. The ordinate on these curves, corresponding to the "swing" due to the magnesium flame was taken as indicating the position of that flame upon the curve. The abscissa reading of this point gave the flame temperature to be inserted in the table. In figure 4 are given the curves for the third method. The galvanometer "swings" for the same flame in the two cases were not exactly the same on account of the bead of metal at the junction being larger in one case than in the other.

Whatever question may be raised touching the accuracy of the absolute values of the above determinations of flame temperatures; there can be little doubt that they are relatively nearly correct; and we may be sure that the temperature of burning magnesium is a little below that of the hottest part of an air blast flame.

When the quality of the light from sources of different temperature is examined, it is almost uniformly found that the light from the sources of higher temperature is richer in the more refrangible rays. Prof. Pickering, in the course of the series of investigations on the quality of the light from different sources already cited, has made use of this fact to calculate flame temperatures. The following passage from his paper will serve to indicate the basis of his estimates: "Then if the temperatures we adopted were correct, this would give us a very simple empirical law, viz: The temperature is always proportional to some function of the ratio of any two assumed wave-lengths. For artificial sources for the wave-lengths ·585 and ·455 it varies directly as this ratio. . . . . Upon this principle the temperature of the magnesium-light, perhaps the highest terrestrial temperature we have yet attained, would be 4900° C." As direct measurement shows this estimate to be altogether too high, it might be inferred that the magnesium light, unlike that of most sources, is not solely due to incandescence, but that it is in part due to something like fluorescence by heating. Further evidence in favor of this view will be presented in the course of the following study of the efficiency of the magnesium light.

III.

Radiant Efficiency of Magnesium light.

By radiant efficiency of a source of light I mean the ratio of *luminous energy* to total *radiant energy*. This ratio has often been rather ambiguously called, *net* efficiency.

The method employed for the determination of this ratio was to note the galvanometer deflections produced by the direct radiation of the source upon the face of a thermopile in circuit with a galvanometer, and then the effect of radiation from the same source when the "dark" heat is cut off by a glass cell containing a saturated solution of alum. Two alum cells were used in all cases. The second cell eliminated the effect of the warming up of the first one due to the absorption of radiant heat. The total thickness of the two alum cells was 72^{mm}. The E. M. F., produced in a thermopile by radiation on its face, varies directly as the intensity of the radiation. Therefore the ratio of the galvanometer deflection obtained when the alum cells are interposed, to the deflection produced by the unobstructed radiation, properly corrected if there has been a change in the resistance of the galvanometer circuit, gives the ratio of the radiation through the alum cells to the total radiation. When this ratio is corrected for the light absorbed and reflected by the alum cells and for the "dark" heat which passes through them, we have the radiant efficiency of the source of light.

The amount of light absorbed and reflected by the alum cells was determined photometrically. The candle power of a constant source of light was measured both when the two alum cells were and were not interposed between it and the photometer, and it was found that ·641 of the light incident upon the face of the first alum cell passed through both. The "dark" heat transmitted by the alum cells was measured with the aid of a cell containing an opaque solution of iodine in bisulphide of carbon. This transmitted the "dark" heat but intercepted the light. In the case of a gas flame ·004 of the incident "dark" heat was transmitted through both alum cells.

For the sake of comparison the radiant efficiency of candle light and gaslight was determined. The final results of a number of measurements are as given below.

TABLE III.

Radiant efficiency of	candle-light,		·0153
" " "	gaslight,	Bat's wing burner,	·0128
		Argand "	·0161

Julius Thomsen* found the efficiency of petroleum flame to be about ·02. His method was similar to the above except that he used distilled water instead of a solution of alum and disregarded the heat transmitted. S. P. Langley† by a very different method, namely by measuring the intensity of the

* Poggendorff's Annalen, cxxv, p. 348. † Science, vol. i, p. 483.

radiation for the different wave lengths of the luminous and heat spectrum, found the radiant efficiency of gaslight from an Argand burner to be ·024.

Considerable difficulty was experienced in measuring this ratio for magnesium light on account of the great variability of the magnesium flame. The galvanometer needle instead of moving steadily or by steps to a maximum and then remaining there, was almost constantly in motion. Furthermore the radiation with and without the alum cells had to be measured successively, and there was no certainty that the condition of the flame was the same in the two cases. The best that could be done was to take a large number of observations and discard a few that were very far from the mean.

TABLE IV.

No. of Experiment.		Galvanometer deflections. Two alum cells R. of circuit =803.	Direct radiation R. of circuit=8030.	Light transmitted through alum cells dividided by total radiation.	Preceding ratio corrected for heat transmitted.	Radiant efficiency (preceding ratio corrected for light reflected and absorbed.)
No.	1	67·4	76·5	·088	·085	·133
"	2	77·5	83·5	·093	·090	·140
		Same as above but with diaphragm.				
No.	3	16·5	17·9	·092	·089	·139
"	4	21·7	22·7	·095	·092	·144
		Same as above but with galvanometer No. 2.				
		R. of circuit=37·46	R. of circuit 147·46			
No.	5	18·0	48·6	·094	·091	·142
"	6	17·8	49·1	·092	·089	·139
"	7	12·4	40·8	·077	·074	·115
"	8	14·1	41·2	·087	·084	·131
		Same as above, sensitiveness of galvanometer changed.				
		R. of circuit=20·46	R. of circuit 207·46			
No.	9	31·0	40·5	·076	·073	·114
Average by method of permanent deflections,						·133

In Table IV, are given nine determinations of the radiant efficiency of magnesium light. In the first two no diaphragm was used, but in every other case a diaphragm of 10×15^{mm} opening was placed in front of the ribbon of burning magnesium. This reduced the fluctuations caused by the varying length of the incandescent strip of magnesia.*

It has been proved† that when a galvanometer and thermopile are used together the "first swing" of the galvanometer

* It is perhaps a misnomer to call this strip of incandescent magnesia a "flame." Neither the combustible nor the product of combustion is a gas and the burning magnesium unlike a flame hangs downward.

† Ernest Merritt, note on galvanometer used with thermopile, this Journal, xli, p. 417.

needle due to the face of the thermopile being suddenly exposed to a source of radiation is proportional to the final permanent deflection. Use was made of this fact in obtaining the results given in Table V. In this case there was no difficulty in determining the limit of the "first swing." The difficulty still remained, however, that the magnesium might be giving out a maximum of radiation at the instant of exposing the thermopile to it while at the next exposure it might be far from a maximum. A mean of the results by the method of permanent deflections and "first swings" gives ·135 as the radiant efficiency of magnesium light. The only artificial light whose efficiency is greater than this is the light from a Geissler tube* of which the radiant efficiency is about ·34. L. B. Marks† finds the radiant efficiency of the arc light to vary from ·08 to ·127 depending upon the character of the carbons.

TABLE V.

No. of Experiment.	Galvanometer "swings." Two alum cells. R. of circuit 7·46	Direct radiation R. of circuit 7·46	Light transmitted through alum cells divided by total radiation.	Preceding ratio corrected for heat transmitted.	Radiant efficiency (preceding ratio corrected for light reflected and absorbed.)
No. 1	3·8	47·0	·081	·078	·122
" 2	3·5	40·0	·088	·085	·133
" 3	2·9	31·8	·092	·089	·139
Sensitiveness of galvanometer changed.					
No. 4	4·9	55·1	·089	·086	·134
" 5	5·2	57·0	·091	·088	·137
" 6	5·0	48·3	·103	·100	·156
" 7	5·4	56·3	·096	·093	·145
" 8	4·6	54·9	·084	·081	·126
" 9	4·3	45·3	·095	·092	·144
Average by the method of "first swings."					·137

H. Nakano,‡ in a series of experiments to determine the relation of the size of carbons to efficiency, found that in the case of carbons ·25 in. in diameter and a potential difference of 38 volts the "spherical efficiency" was ·166 but with carbons of the usual size the efficiency was about ·10.

The radiant efficiency of incandescent lamps is much less than that of the arc light. Ernest Merrit§ found the radiant efficiency of incandescent lamps under the best conditions compatible with their continued existence to be about ·06.

In all the experiments above referred to, the efficiency was measured in the same way, viz: by taking the ratio of the

* Beiblätter zu den Annalen der Physik, xiv, page 538.
† Am. Inst. of E. E., 1890, vol. vii. ‡ Am. Ins. of E. E., vol. vi, p. 308.
§ This Journal, vol. xxxvii, p. 167.

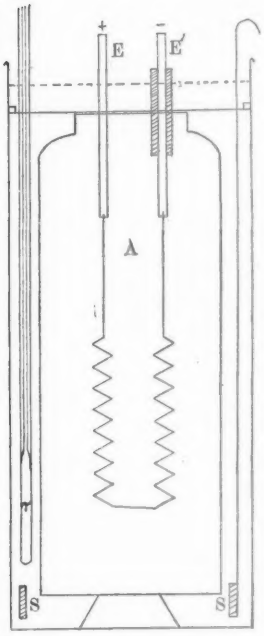
radiation through an alum cell to the unobstructed radiation and correcting for light absorbed and heat transmitted.

IV.

Heat of Combustion of Magnesium.

In order to determine the total efficiency of magnesium light it is necessary to know its heat of combustion. In determining this quantity a new form of colorimeter was used. In this case the magnesium ribbon was burned in an entirely closed vessel containing oxygen, not allowing *any* of the products of combustion to escape. Figure 5 represents a vertical section of the calorimeter. The smaller vessel, A, holds something over half a liter. This vessel is provided with an air-tight cover through which pass two electrodes E, E′, one of which is insulated from the calorimeter. The outside vessel is just large enough to allow room between it and the inner vessel for a stirrer, S, and a thermometer T.

5.



The process was as follows: About three fourths of a gram of magnesium was coiled into a spiral and a very small quantity of phosphorus fastened to it. The terminals of the spiral were then connected to the electrodes. Before putting the magnesium into the vessel, A, the latter was filled with oxygen. After the inner vessel had been closed, water was poured into the calorimeter until it was a centimeter deep over the top of the former vessel. The ribbon was then ignited by the instantaneous application of a current of electricity. This calorimeter gave quite uniform results. In Table VI, are given

TABLE VI.

No.	Lesser calories per g. of Mg.	No.	Lesser calories per g. of Mg.
1	6246	5	6020
2	6081	6	6072
3	5760	7	6011
4	5878	Average.	6010

the results of seven determinations by this method. A mean of these gives 6010 lesser calories as the heat developed by the combustion of one gram of magnesium in oxygen.

Julius Thomsen* gives 6077 as the heat of combination of magnesium and oxygen. He arrived at this result indirectly by means of the heat developed in the formation of the hydrate.

V.

Total efficiency of magnesium light.

By total efficiency is meant the ratio of luminous energy to the total energy expended in the production of the light. In order to determine this ratio it is necessary to know the ratio of radiant energy to total energy of combustion. The method of obtaining the energy of combustion of a gram of magnesium in lesser calories, has just been described, and next must be indicated that of obtaining the radiant energy from a gram of burning magnesium in the same units. The method of obtaining this result was by calibrating the galvanometer and thermopile for lesser calories of spherical radiation from a source 24^{cm} from the face of the thermopile. The known source of heat was a spherical brass vessel coated with lamp black and filled with hot water. Its loss of heat was known by its fall in temperature. The loss by convection and conduction was determined by noticing the rate of cooling in air and in a vacuum, under otherwise similar circumstances. By this means it was found that a galvanometer "swing" of one scale division corresponded to a spherical radiation of 2·53 calories per minute. Next the thermopile was exposed to the radiation from burning magnesium, the ribbon being supplied at a uniform rate. From a mean of 24 observations it was found that the burning of one gram of magnesium produced 4630 calories of radiant energy. As above shown ·135 of this radiant energy is light. The total energy of combustion of one gram of magnesium is 6010 colories, therefore the total efficiency of magnesium as a producer of luminous energy is $\frac{\cdot 135 \times 4630}{6010} = \cdot 1025$.

It is assumed in this computation that the radiation from burning magnesium is of the same intensity in all directions. Experiments were made for determining the validity of this assumption, in which it was found that the candle power showed but little diminution up to 70° from the horizontal plane.

It is very remarkable that nearly ·10 of the total heat of combustion of any artificial illuminant is expended in producing light. The radiant efficiency of magnesium, as we have

* Journal für praktische Chemie, 1875.

seen, is very high and what is still more surprising, the ratio of radiant energy to total energy is not far from ·75. The small loss by convection which renders this ratio possible is partially explained by the fact that the product of combustion is a solid. It may be also that this unusually high percentage of radiation is in some way related to the fact that so large a proportion of the radiant energy itself is luminous.

The final experiments in my study of magnesium as a source of light consisted in the determination of the amount of light produced by burning one gram of the metal. Measurements were made by means of the "horizontal slit" photometer. The standard for four determinations was an Argand lamp with a Methven slit, which allowed two candle power to pass through. In these measurements the comparison was made at the D line. In four other determinations the standard was an incandescent lamp; in which case the measurements were made at two points on opposite sides of the D line and their mean taken. In Table VII are given the final results of these eight determinations.

TABLE VII.

Standard = Argand lamp.		Standard = Incandescent lamp.	
No.	C. p. minutes per g. of Mg.	No.	C. p. minutes per g. of Mg.
1	248	1	233
2	252	2	236
3	228	3	288
4	250	4	272

A mean of the above eight measurements gives 251 candle-power-minutes produced by the combustion of one gram of magnesium.

This measurement of the candle-power-minutes produced by one gram of magnesium may serve as a check on the determination of the total efficiency. Assuming that the efficiency is ·10, one gram produces 601 calories of luminous energy; therefore the thermal equivalent of one candle-power-minute of magnesium light is $\frac{\cdot 10 \times 6010}{251} = 2{\cdot}39$ calories. Even in the most unfavorable circumstances, namely, by using the maximum heat of combustion from Table VI and the minimum candle power minutes from Table VII we have, thermal equivalent $= \frac{\cdot 10 \times 6246}{228} = 2{\cdot}74$ lesser calories. In 1865 Julius Thomsen* published some determinations of the thermal equivalent of light, which he found to vary from 4·4 calories in the case of

* Annalen der Physik und Chemie, vol. cxxv, page 348.

a sperm candle to 3·7 calories in the case of gas. His values are too high, for he used distilled water to absorb the radiant heat instead of an alum solution, and made no correction for the heat transmitted. Dr. Nichols* puts the thermal equivalent of the light from an incandescent lamp at 3·6 calories. Magnesium-light is much richer than gaslight in those rays (green) which are most effective in producing vision. Nevertheless it is highly improbable that its thermal equivalent is much less than two-thirds that of the incandescent lamp or in other words, that it is much less than 2·4 calories. But if the total efficiency of magnesium light is considerably less than ·10 then its thermal equivalent must be considerably less than 2·4 calories.

It may be interesting to compare magnesium with gas as a producer of luminous energy. The radiant efficiency of gaslight is about ·015; but of the total energy of combustion in the case of gas only ·15 or ·20 is radiant energy. Therefore the total efficiency of gaslight is ·0022 or ·003. This means that potential energy in the form of uncombined magnesium and oxygen is from 30 to 40 times more effective as a producer of luminous energy than the same quantity of potential energy in the form of illuminating gas and oxygen. Even this statement does not give the full measure of the superiority of magnesium light. If the thermal equivalents of gaslight and magnesium light are 3·6 and 2·4 respectively, the same quantity of luminous energy in the form of the latter will produce 50 per cent more candle power than if it were luminous energy in the form of gaslight.

The results of this investigation may be summed up as follows:

1. The spectrum of burning magnesium, as has already been pointed out by Pickering, approaches much more nearly that of sunlight than does the spectrum of any other artificial illuminant.

2. The temperature of the magnesium flame, about 1340° C., lies between that of the Bunsen burner and that of the air blast lamp, although the character of its spectrum is such as would correspond to a temperature of nearly 5000° C. were its light due to ordinary incandescence.

3. The "radiant efficiency" is 13½ per cent; a value higher than that for any other artificial illuminant (excepting perhaps the light of the electric discharge in vacuo for which Dr. Staub of Zürich has found an efficiency of about 34 per cent.

4. The radiant energy emitted by burning magnesium is about 4630 calories per gram of the metal burned or 75 per

* American Inst. of E. E., vol. vi, p. 173.

cent of the total heat of combustion; as compared with 15 per cent to 20 per cent in the case of illuminating gas.

5. The thermal equivalent of one candle-power-minute of magnesium light is about 2·4 lesser calories, as against 3·5 to 4·0 for other artificial illuminants.

6. The total efficiency of the magnesium light is about 10 per cent; as compared with ·25 per cent [a quarter of one per cent], for illuminating gas.

7. Taking into consideration the greater average luminosity of the rays of the visible spectrum of the magnesium flame, it is certain that *per unit of energy expended, the light-giving power of burning magnesium is from fifty to sixty times greater than that of gas.*

Physical Laboratory of Cornell University, June, 1891.

ART. XXXVII.—*A method for the quantitative separation of Barium from Calcium by the action of Amyl Alcohol on the Nitrates;* by P. E. BROWNING.

[Contributions from the Kent Chemical Laboratory of Yale College—XII.]

THE fact that strontium can be separated quantitatively from calcium by boiling the nitrates with amyl alcohol, as I have recently shown,* naturally suggested a similar separation of barium from calcium by the same general treatment. Solutions of specially purified barium and calcium nitrates were prepared and standardized, either by the evaporation or filtration of definite portions after treatment with sulphuric acid. The mean of several closely agreeing results, both by evaporation and filtration, was taken as the standard. The method followed was essentially the same as described in the method for the quantitative separation of strontium from calcium referred to above. The first series of experiments was directed toward an investigation of the action of amyl alcohol upon barium nitrate alone. Accordingly definite amounts of the barium salt were measured into Bohemian beakers of about 100cm³ capacity and weighed. The water was then evaporated over a water bath, and the dry salts dissolved in a few drops of water and boiled with 30cm³ of amyl alcohol, that amount being determined upon as convenient, until the normal boiling point of the alcohol was reached—128° to 130° C. During the boiling the beaker was placed upon a piece of asbestos board about 15cm square to keep the inflammable fumes of the alcohol from the flame. When the temperature

* This Journal, vol. xliii, p. 50.

of the alcohol reached its normal boiling point the beaker was removed and the barium nitrate filtered off upon an asbestos felt in a perforated platinum crucible, the crucible and felt having been previously dried and weighed. The filtration was carried on under gentle pressure, the filtrate being received in a beaker standing under a bell jar upon a ground glass plate. The last traces of barium nitrate were removed from the beaker by washing with small amounts of anhydrous amyl alcohol contained in a wash bottle, previously described, to the mouth piece of which a small chloride of calcium tube was connected. The crucible containing the barium nitrate was placed in an air bath and heated to 150° C. The process of heating and weighing was repeated until a constant weight was obtained. Series I shows the results of these experiments the barium being calculated as oxide.

SERIES I.

	BaO taken.	BaO found.	Error.
(1)	0·1040 grm.	0·1039 grm.	0·0001 grm. —
(2)	0·1043 "	0·1043 "	0·0000 "
(3)	0·0524 "	0·0522 "	0·0002 " —
(4)	0·0519 "	0·0518 "	0·0001 " —

These results show plainly enough the complete insolubility of the barium salt in the amyl alcohol; but to confirm them the filtrates of (3) and (4) were evaporated to dryness, ignited to burn off any organic matter from the amyl alcohol, treated with sulphuric acid, heated to low redness and weighed. The weights in both cases showed the absence of any residue.

SERIES II.

	BaO taken. grams.	BaO found. grams.	Error. grams.	CaO taken. grams.	CaO found. grams.	Error. grams.
(5)	0·1410	0·1406	0·0004 —	0·0112	0·0114	0·0002 +
(6)	0·1300	0·1301	0·0001 +	0·0926	0·0926	0·0000
(7)	0·1043	0·1049	0·0006 +	0·0741	0·0736	0·0005 —
(8)	0·0781	0·0781	0·0000	0·0556	0·0554	0·0002 —
(9)	0·0525	0·0526	0·0001 +	0·0373	0·0372	0·0001 —

SERIES III.

	BaO taken. grams.	BaO found. grams.	Error. grams.	CaO taken. grams.	CaO found. grams.	Error. grams.
(10)	0·1304	0·1308	0·0004 +	0·0927	0·0921	0·0006 —
(11)	0·1043	0·1046	0·0003 +	0·0371	0·0370	0·0001 —
(12)	0·1037	0·1036	0·0001 —	0·0743	0·0744	0·0001 +
(13)	0·0783	0·0776	0·0007 —	0·0427	0·0422	0·0005 —
(14)	0·0519.	0·0521	0·0002 +	0·0369	0·0361	0·0008 —
(15)	0·0519	0·0512	0·0007 —	0·0570	0·0567	0·0003 —
(16)	0·0261	0·0259	0·0002 —	0·0925	0·0925	0·0000

The next experiments were directed toward a separation of barium and calcium nitrates. Definite amounts of a solution of barium nitrate were measured from burettes into counterpoised beakers and weighed, as already described, the calcium nitrate was then added in solution and the weight taken again. The water was evaporated and the dry salts dissolved again in the least possible amount of water, and boiled as before with 30cm³ of amyl alcohol. The barium salt was filtered off into a perforated platinum crucible containing an asbestos felt, dried and weighed as previously described. The calcium was determined in the filtrate, in the form of the sulphate, by evaporation of the alcohol, treatment with an excess of sulphuric acid and ignition. Series II gives the results of this treatment.

In Series III the effect of a double treatment with the alcohol is recorded. In these experiments, after the first boiling, already described, the alcohol was decanted upon an asbestos felt, under the conditions previously mentioned, and collected in a beaker placed to receive it. The residue was then dried at a gentle heat over a radiator to remove amyl alcohol, dissolved in a few drops of water, and this solution was treated with a drop of dilute nitric acid to assure the condition of nitrate, and evaporated to dryness. After dissolving in a few drops of water, 30cm³ of alcohol were added, and the boiling repeated. The residue was filtered off upon the felt through which the first portion had been decanted and washed with amyl alcohol, care being taken to remove all particles from the beaker by careful rubbing. The crucible and residue were heated to 150° C. as before and weighed. The results after one treatment are fully as satisfactory as those after the double treatment,—a point which simplifies the method considerably. In the separation of strontium from calcium the double treatment was necessary. The form in which the salts separate suggested a possible explanation. The strontium nitrate separates in plate-like masses, while the barium is much more granular and therefore less liable to include foreign matter.

Series IV contains the results of certain experiments directed toward the separation of barium and strontium together from calcium. Definite portions of the three nitrate solutions were measured into counterpoised beakers and the successive weights taken as previously described. The method of treatment was the same as that described in the double treatment of the barium and calcium salts. The correction for the solubility of the strontium salt was applied (0·001 grm. of strontium oxide to 30cm³ of the alcohol used) in the manner defined in the paper upon the separation of strontium from calcium. The results are tabulated for the nitrates in the cases in which barium and strontium were treated together, but the errors are also aver-

aged on the oxides for the amounts of barium and strontium nitrates taken in order that they may be compared more conveniently with the results of the previous series.

SERIES IV.

	$Ba(NO_3)_2$ and $Sr(NO_3)_2$ taken.	$Ba(NO_3)_2$ and $Sr(NO_3)_2$ found and corrected.	Error in nitrates.	Error averaged and calculated as oxide.	CaO taken.	CaO found.	Error.
	grams.	grams.	grams.	grams.	grams.	grams.	grams.
(17)	0·3941	0·3945	0·0004 +	0·0002 +	0·0283	0·0277	0·0006 —
(18)	0·1436	0·1442	0·0006 +	0·0003 +	0·0568	0·0558	0·0010 —
(19)	0·3163	0·3152	0·0011 —	0·0006 —	0·0284	0·0274	0·0010 —
(20)	0·1978	0·1987	0·0009 +	0·0005 +	0·0285	0·0280	0·0005 —
(21)	0·1948	0·1932	0·0016 —	0·0008 —	0·0833	0·0835	0·0002 +
(22)	0·1971	0·1971	0·0000	0·0000	0·0830	0·0817	0·0013 —
(23)	0·1973	0·1960	0·0013 —	0·0007 —	0·0830	0·0824	0·0006 —
(24)	0·1959	0·1970	0·0011 +	0·0005 +	0·0830	0·0819	0·0011 —
(25)	0·1971	0·1963	0·0008 +	0·0004 +	0·0834	0·0831	0·0003 —

In experiments (21), (25) 15cm³ of the alcohol were used in each boiling instead of the 30cm³ of the previous experiments, and thus the total amount of the corrections for the solubility of the strontium salt was reduced one-half. In experiments (21), (23) and (25) the calcium was determined by precipitation with sulphuric acid, the precipitate being filtered off, ignited at low redness and weighed.

The rapidity of execution and satisfactory character of the results of this method of separating barium from calcium seem to place it among good analytical methods.

ART. XXXVIII.—*On Plicated Cleavage-Foliation;* by T. NELSON DALE.

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THE schists and slates of the Taconic Range in Western Massachusetts and Vermont afford a good field for studying the various phases of cleavage: slaty-cleavage, slip-cleavage,* close-joint-cleavage. Some of the results of such a study have been published in outline by the writer,† and others are in course of preparation.

De la Beche‡, and later Charles Darwin§ noticed that the upturned cleavage laminæ of clay-slate were sometimes curved at the surface, and Dr. Hans Reusch of Christiania‖ cites an

* "Ausweichungs-clivage" of Heim; "strain-slip cleavage" of Bonney.

† The Greylock Synclinorium. American Geologist, July, 1891.

‡ Geological Manual, p. 42, 1831.

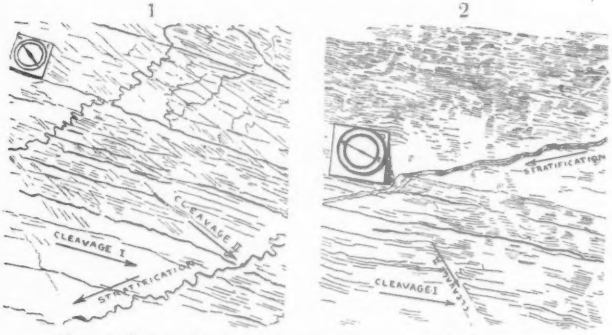
§ Geological Observations on Coral Reefs, Volcanic Islands and on South America, Part III, p. 160, London, 1851.

‖ Bommelφen og Kommφen med omgivelser, p. 196, Kristiania, 1888.

interesting case on the Hardanger fiord in which the cleavage planes traversing a plicated layer have themselves been plicated along with the former by secondary pressure.

After examining many square miles of the Taconic schists, the writer found last summer a case of this kind at West Rutland, Vt. Although the structure is not as extreme as that described by Dr. Reusch it involves identical principles. Moreover the evidences of stratification at this locality are so conclusive as to separate distinctly the two foliations.

The exposure is on the south side of a vertical E.–W. joint face in a mass of sericite schist on the west side of the West Rutland valley. Traversing it with a very low westerly dip are several layers 1–3 inches thick and from 1–5 feet apart of calcareous schist which determine at once the direction of the stratification. Across this occurs the prevailing cleavage-foliation of the region, dipping about 30° east. Parallel with these small calcareous beds a highly plicated foliation is seen in places, and there are also indications of a second system of cleavage planes dipping at high angle east, about 80°. (See fig. 1).* In the lower and eastern part of the ledge the prevailing cleavage-foliation (I) undulates in gentle folds which measure about one inch in width.

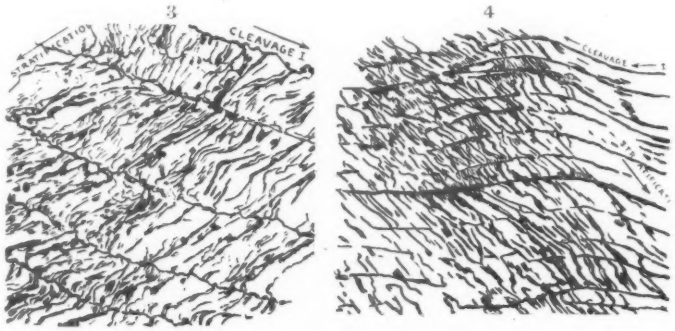


Figs. 1, 2, from photographs, the compass is 4 inches square.

See fig. 2 which shows also one of the smaller westerly dipping calcareous beds. A specimen taken here from between the calcareous beds would be utterly misleading for it would only show a gently undulating foliation dipping low east crossed by another dipping high east neither of which however is stratification-foliation.

* In this and the other illustrations the exact relations of the foliation to the horizon are not preserved but only their mutual relations.

Fig. 3 shows the microscopic structure. The dominant cleavage is evidently slip-cleavage, and the cleavage-foliation itself shows in places extremely minute plications.



Figs. 3, 4, from photographs of thin sections; 3, section 0·12 in. sq.; 4, section 0·30 in. sq, the directions of the dip are here figured reversed.

Fig. 4, under less enlargement, shows the flexure of the cleavage-foliation which in this specimen is considerable. In both figs. 3 and 4 the prominence of the cleavage-foliation is due to the infiltration of ferruginous matter.

The steps in the formation of this structure appear to have been:

1. Plication of the beds and consequent cleavage-foliation (I), slip-cleavage.
2. Plication of cleavage-foliation (I) in consequence of secondary pressure operating in the direction of the cleavage dip.
3. Cleavage-foliation (II), slip-cleavage passing into close joint cleavage, produced by the plication of cleavage-foliation I.

This subject is not only of interest structurally but in some regions may be of economic importance.

Newport, R. I., Jan. 2, 1892.

Art. XXXIX.—*Geological Age of the Saganaga Syenite;* by A. R. C. Selwyn.

I am surprised to read in a paper by H. V. Winchell* upon the age of the Saganaga syenite the statement that this Saganaga syenite was always supposed to be Laurentian. A glance at the Canadian Geological map, 1882, shows it as occurring with an extensive area of Huronian. That it should be

* This Journal, vol. xli, May, 1891.

accompanied by Keewatin schists is therefore quite probable and that it is of Huronian not Laurentian age has always been supposed by Canadian geologists who have examined it. I am gratified to learn that this fact is now apparently recognized by Mr. H. V. Winchell.

A few remarks on the use of the names Huronian, Coutchiching and Keewatin are I think called for in view of the very erroneous ideas that have been promulgated, and of which the paper now referred to is an instance, respecting the Huronian system in Canada and the attempt to subordinate it to new and comparatively unknown names or to confound it and associate it with Paleozoic formations with which it has nothing in common. It is even indicated as Huronian on the map of 1866, though then the extent of it as also of many other similar areas had not been ascertained.

The name Keewatin as well as Coutchiching was originated on this Survey by Dr. Lawson. I sanctioned the use of these names in the Survey publications, but only as being useful to designate subdivisions, more or less local, of the great series of Archæan rocks, which is widely distributed in Canada, at intervals from Belle Isle Strait and Labrador to Lake Winnipeg, and thence perhaps to the Arctic Ocean and which has always been known and described wherever it has been recognized in Canada, as Huronian or Upper Archæan. The name Huronian is not, and never was used in Canada as equivalent to Taconic. The latter term, so far as I can make out, like Quebec Group, as depicted on the published maps, included parts of all the formations from Huronian up to Hudson River shales inclusive. Huronian, on the other hand, was always supposed to occupy in Canada one and the same interval in geological time, viz: that antedating the lowest Paleozoic. It was never supposed, like Taconic, to include Paleozoic formations though areas of it had in error been included in them. The Keewatin area of the Lake of the Woods had always been recognized as Huronian and the Keewatin schists are simply one lithological subdivision of that wide spread system. Perfectly similar schists occur in some portion of all the Huronian areas shown on the Geological map of Canada, 1882, and everywhere the system presents similar characters, mineral, lithological and physical, and, as I said of these rocks in 1879, they are largely of volcanic and igneous origin. Clastic, pyroclastic or aqueo-igneous and massive igneous rocks are intimately associated and interbedded and all have been subjected to such intense and long continued dynamic and thermochemic metamorphism as often to have obliterated their original characters. Microscopic investigation is now proving the correctness of this somewhat old strati-

graphic generalization. Large areas that will eventually be classed with the Huronian system have been colored on the geological maps of Canada as Laurentian. These areas however had never been and even yet are not examined. A comparison of the map of Canada of 1866 with that of 1882 indicates, though only partly, the extent of this error, and the advance of our knowledge of the distribution of Huronian in the interval. Thousands of square miles of territory in Northern Canada remain to be explored before all the areas occupied by the rocks of the Huronian system can be defined. Unfortunately the literature of the system has gone very far ahead of the knowledge of it derived from personal observation in the field. I have probably examined these rocks in the field over a wider geographical extent than any other geologist but have taken little part in the literature respecting them. I have however strongly deprecated the term "typical Huronian," and then using the very imperfect descriptions given in the early reports of the Canadian Survey of one small partially mapped area, viz: that on the shore of the north channel of Lake Huron, in arguments against the subsequent correlation with it of other areas. The chief arguments being based on the local greater development of some particular kind of rock as quartzite, etc., and low angles of dip--the latter being, however, if not indeed both, a wholly incorrect assumption. That it is so as regards the latter can be proved by the maps of the so-called "typical" area made by Mr. Murray and published in 1857 in atlas form.

Local development of any particular kind of rock is of no import in the correlation of systems, neither are high or low dips. The Archæan rocks in Canada, Laurentian and Huronian, are sometimes flat and locally dip at all angles, from that to vertical and yet low dips and local lithological characters have been the main reasons adduced by some of the writers on Huronian against the correlations made by the Canadian Survey, all of which are, however, based on careful observation in the field, and are as well founded as, in the absence of paleontological evidence, is possible. Every other kind of stratigraphic evidence is present and I hold it amply sufficient for the purpose of stratigraphic correlation.

In the present state of our knowledge of Archæan formations no new name is required in Canada, for this great system. As its subdivisions become worked out, local names, as Coutchiching and Keewatin, can be used to designate them, and if, as is possible, though I think not probable, some part of it should eventually be proved, by the discovery of fossils, to belong to the Paleozoic era, it can be separated under some appropriate designation.

A still more glaring error is to correlate Animikie—plainly lower Cambrian, at least in Canada—with Huronian, with which it has scarcely any feature in common. The difference in degree of metamorphism exhibited under the microscope has no necessary relation to age, but is dependent on local circumstances and probably still more on original characters. There is no recognizable unconformity in this great Huronian series, and the rocks composing it undoubtedly all belong to the same rock-making era. The lapse of time represented may be less than, or it may exceed, that of all subsequent rock-making periods. On this point there is absolutely no evidence, neither is there that it represents other than an unbroken and very early, if not the earliest, series of events in the history of the evolution of the stratiform rocky crust.

An important area of very characteristic Huronian rocks has been recognized, during the past summer, on the east shore of Lake Winnipeg, greenstones, "slate conglomerates," Keewatin schists, etc.

I have recently visited the districts of Madoc and Marmora and I should now have no hesitation in, at least provisionally, correlating the Hastings series of the late Mr. Vennor with the Huronian, to which he himself surmised it was more nearly related than to Laurentian.

ART. XL.—*A Third Occurrence of Peridotite in Central New York;* by C. H. SMYTH, JR.

IN view of the interest attaching to the demonstration by Professor G. H. Williams, of the igneous nature* of the so-called serpentine of Syracuse, N. Y., any further occurrence of similar rocks in this region seems worthy of note.

A recent paper† describes several dikes near Ithaca, N. Y., consisting of a rock closely related to the Syracuse peridotite. In both of these localities the dikes are associated with nearly horizontal, undisturbed strata, differing in this respect from the rock described in the present paper. This rock occurs in the form of a narrow dike in a fault plane at the village of Manheim or East Creek, seven miles east of Little Falls, N. Y. The dike is mentioned by Vanuxem in his description of the

* G. H. Williams: The Serpentine (Peridotite) occurring in the Onondaga Salt Group at Syracuse, N. Y., this Journal, 1887, p. 144. Also Bull. Geol. Soc. Amer., vol. i, pp. 533, 534.

† J. F. Kemp: Peridotite Dikes in the Portage Sandstones near Ithaca, N. Y., this Journal, November, 1891, p. 410.

"Uplifts of the Mohawk,"* and is spoken of in the papers above cited, though never visited by the authors.

The fault, which involves the strata from Archæan to Utica slate, is plainly shown at the highway bridge over the East Canada Creek, a short distance north of the railroad. Here the Utica slate forms a wall ten feet high on the east side of the creek, while the corresponding western wall, about eight hundred feet away, is Calciferous sand-rock. The strata on both sides are horizontal, but as the contact between the two formations is covered by stream deposits, there may be, and probably is, a flexure of the rocks near the fault. The strike of the fault is about N. 20 E., coinciding with the direction of the valley. One mile farther up stream the strike of the fault changes to N. 40 E. crossing the stream, and thus producing a considerable fall, the sand-rock here rising above the slate in a bluff over one hundred feet high. At this point, the contact between the sand-rock and the slate is shown, and there is a marked disturbance of the latter. Two hundred feet back from the fault the slate begins to bend slightly upward, and the inclination rapidly increases, till at the fault the dip approaches 90°. At the same time, the flexure brings to view the underlying strata of Trenton limestone. As would be expected, the thick bedded calciferous sand-rock on the upthrow side is much less affected, being bent downward very slightly.

It is at this point, near the foot of the falls and on the east side of the creek, that the dike occurs, filling a space ten inches wide in the plane of the fault between the sand-rock and the slate. In connection with the dike is a one inch vein of calcite carrying galenite and pyrite, and some fifty years ago, with a view of working this vein, a drift was run in about sixty feet, when the dike pinched out. In the opposite direction the dike passes under the creek and does not extend to the west bank. It is, therefore, not more than one hundred and fifty feet in length. However, it seems probable that the rock exists at other points along the fault, being covered by drift.

The rock is granular and of a dark green or gray color, with a mottled appearance due to the presence of a light green, to white, mineral. Scattered through it are abundant plates of dark brown mica, often 6–8^{mm} in diameter. The appearance of the rock varies but slightly, excepting when it has been weathered. In the latter case the product is a light yellow, pulverulent clay, with scales of mica scattered through it. Microscopic study shows the rock to be made up largely of olivine, with less mica, in a ground mass chiefly crystalline. The porphyritic structure is distinct and constant, with but

* Geology of New York, Part III, pp. 207, 208.

slight variations in the relative proportions of the constituents. The most abundant mineral is olivine, occurring both in irregular grains, and with sharp crystal outline. The diameter of individuals seldom exceeds 1^{mm} though larger masses are occasionally seen. Twinning parallel to 011 is rare, having been noted in only two slides. Inclusions are not very abundant, and show no regularity of arrangement. The usual alteration to serpentine and carbonates is shown along the cracks, and in some cases the original substance is entirely changed, but this is not common, much of the olivine generally being present.

The large mica phenocrysts rarely show hexagonal outline. The color in thin sections is dark brown, with marked pleochroism. Cleavage plates of the mineral give, with convergent polarized light, a figure which differs but slightly from that of a uniaxial mineral. The mica is doubtless biotite. While some individuals are quite fresh, others show considerable alteration to carbonates. Occasional crystals of rhombic pyroxene are present, but hardly in sufficient quantity to be considered an essential constituent of the rock.

Though a large proportion of the ground-mass is distinctly crystalline, a glassy substance is present in small quantity, and numerous patches of nearly isotropic material probably represent a glass that has been slightly altered. Of the crystalline portion of the ground-mass, biotite is perhaps the most abundant member. It appears in irregular lath-shape particles, generally quite fresh and showing the usual pleochroism. The arrangement of the particles sometimes shows a decided flow structure. Next in order of abundance is the iron oxide, which occurs both irregular and with octahedral outline, and is evidently a primary constituent of the rock. As it is strongly attracted by the magnet and readily soluble in acids, it is undoubtedly magnetite. Indeed, the former property is so marked and the mineral so abundant, that pieces of the rock $\frac{1}{2}$ inch in diameter may be lifted by a weak magnet. Mingled with the magnetite, both in the ground-mass and as inclusions, are numerous small octahedra never more than $0{\cdot}12^{mm}$ in diameter and usually less than half that size. The octahedral form as a rule is distinct, but irregular grains are also present. The color is deep yellow and the index of refraction high, giving strong marginal reflection. With crossed nicols the crystals are seen to be not perfectly isotropic. When the rock powder is treated with hydrochloric acid the crystals are left in the residue, but are completely dissolved by sulphuric acid. These facts show the mineral to be perofskite. The same conclusion is reached upon comparing the mineral with the perofskite of other American peridotites, their appearance and properties being precisely the same. Some sections of the rock show

still another constituent of the ground mass, of imperfect lath shape, and in color white, green or brown. There is a pronounced fibrous structure, perpendicular to the long axis, producing an appearance very similar to that resulting from the serpentinization of olivine along cracks. Both single and double refraction are high and extinction is parallel. The long axis is sometimes that of greatest, and sometimes of least elasticity in the section, showing the plane of the optic axes to be perpendicular to the long axis. This is also proven by the behavior of the mineral in convergent light. The mineral is decomposed by hydrochloric acid giving a jelly easily stained by fuchsine, and its color changed to red by ignition. All of these characteristics indicate that the mineral is olivine, in partially developed crystals. But in view of the rarity of a second generation of olivine in porphyritic rocks, it is possible that further study of better material may modify this conclusion.

The highly basic character of the rock indicated by its mineralogical composition, is clearly shown by a partial analysis given below. For comparison, the figures for the same constituents are reproduced from published analyses of other rocks of like nature.

	I (Smyth).	II (Morrison).	III (Peter and Kastle).	IV (Hunt).
Loss on ign.	15·20	12·67	16·55	12·77
SiO_2	33·80	37·44	29·43	40·67
Al_2O_3	6·84	28·60	2·36	5·13
Fe_2O_3	12·26	11·92	9·06(FeO)	8·12(FeO)
CaO	9·50	5·45	6·94	----
MgO	21·38	1·97	31·66	32·61
Sp. gr.	2·732	----	2·697	----

I. Manheim Dike.
II. Ithaca Peridotite.*
III. Elliot Co., Ky., Peridotite.†
IV. Serpentine from Syracuse Peridotite.‡

The lack of closer agreement in composition of these four nearly related rocks, is readily explained by the strong tendency to decompose manifested in all members of this very basic group. But despite decided variations, they are all very low in silica and, with the exception of No. II, high in magnesia and iron. The altered condition of the Manheim rock is shown by the loss of 15·2 per cent on ignition, and by its ready effervescence with acids. Though the iron was determined as Fe_2O_3, it doubtless exists in the rock as FeO and Fe_3O_4. The

* This Journal, vol. xlii, p. 412.
† Bulletin 38, U. S. G. S., p. 24.
‡ This Journal, vol. xxxiv, p. 138.

large percentage of lime is partly derived from the material of the adjacent vein, the dike having been broken by movements subsequent to its cooling, and re-cemented by infiltration. That there have been several such movements along the fault plane is shown by a series of slickensided vein surfaces, each slickenside having been covered by a layer of vein stuff, thus affording a smooth surface for the recording of the next movement.

The foregoing evidence, microscopic and chemical, is sufficient to class the rock of the Manheim dike as a member of the peridotite group, and of that division of the group to which Lewis* has given the name kimberlite. It is a well known fact that the peridotites are, of all igneous rocks, the least prone to produce contact metamorphism, and when to this is added the fact of the extreme narrowness of the dike, it is not surprising that no clear evidence is given of any effect upon the enclosing rocks. Diligent search was made for fragments of these rocks included in the dike, but none were found.

Through the kindness of Professors G. H. Williams and J. F. Kemp, the writer has been enabled to compare sections of the Manheim rock with sections of the peridotites of Syracuse, Ithaca, Elliot Co., Ky.,† and Pike Co., Arkansas.‡ The Manheim rock differs from that of Syracuse in having magnetite instead of chromite and in the absence of pyroxene as an essential constituent. In the former respect it resembles the Arkansas rock, and in the latter, the Kentucky rock. In having olivine in the ground mass the Manheim rock differs from all the others. But in spite of these slight variations, the five rocks are closely related. It is interesting to note the unfailing presence of perofskite in the rocks of these widely separated localities.

As regards the age of the Manheim dike, it is certainly younger than the Utica slate, and its mode of occurrence is such as to indicate, with some degree of probability, the time of intrusion. The fault in which the dike occurs is one of a series of eight or more parallel faults, beginning near Amsterdam on the east and occurring at irregular intervals from there to Little Falls. These faults affect the rocks from the Archæan gneisses through the Utica slate. The throw is not large and varies a good deal, but the strike is always north, to northeast. The simplest explanation of these faults is that offered by Vanuxem fifty years ago, that they mark the western extension of the forces of the Appalachian uplift. If this be true, it fixes the intrusion at the close of the Carboniferous, unless it be assumed that the fissure was not filled when first formed, which seems highly improbable. Periods of oro-

* H. C. Lewis: The Genesis of the Diamond, Science, viii, p. 345.

† J. S. Diller: Peridotite of Elliot Co. Ky.. Bulletin,38, U. S. G. S.

‡ J. C. Branner, R. N. Brackett: The Peridotite of Pike Co., Ark., this Journal, July, 1889, p. 50.

graphic movement are periods of igneous activity, which fact of itself, suggests this as the time of intrusion. In view of this fact, as well as the similarity of the rocks, it is a natural conclusion that the dikes of Manheim, Syracuse and Ithaca are of the same age, dating from the close of the Carboniferous.

In this connection it is interesting to note that Mr. Diller* suggests the close of the Carboniferous as perhaps being the time of extrusion of the Elliot Co., Ky., peridotite, which cuts Carboniferous strata, though the very slight disturbance in that locality leads him to think a later date more probable.

Geological Laboratory, Hamilton College, Clinton, N. Y.

Art. XLI.—*A Fulgurite from Waterville, Maine;* by W. S. Bayley.

Through the kindness of Mr. G. K. Boutelle of Waterville, Me., the museum of Colby University has come into the possession of a fragment of fulgurite, which, when unearthed from the midst of a heterogeneous collection of unlabeled rock and mineral specimens, was found to be wrapped in a scrap of paper containing the following inscription:

"This sand tube was taken out of the garden of —— Gilbert, some feet below the surface, after a thunder storm, during which a stroke of lightning was seen to fall on to his garden, where, after having torn up beans and other vegetables in an odd manner, it was tracked by a long tube descending through the soil and sand. I had one specimen which my children broke, into which I could put two fingers—this was from a part lower down. The garden is on the left hand side going to Crummett's Mills bridge, a little more than half way from the Universalist church to the bridge."

No date nor signature accompanies the inscription, nor can any one be found in Waterville who knows more of the incidents connected with the history of the tube than the paper itself reveals. The church mentioned is in the southern portion of the city, and the bridge spans the Messalonskee River, which crosses the main road running west from Waterville about half a mile west of the church.

The sand covering the surface in the region indicated by the above description is probably glacial. It consists of intermingled angular and rounded grains of quartz, feldspar and hornblende, and fragments of some green earthy material and slate.

The portion of the tube that has been preserved measures about three inches in length and has a rudely elliptical cross section with axes of an inch, and three quarters of an inch,

§ Bulletin 38, U. S. G. S., p. 29.

respectively. Its exterior surface is very rough and is thickly covered with sand grains, while its interior is glazed with a transparent coating of light yellowish green glass about a millimeter in thickness. This glass with its adhering sand grains compose the tube. A very close inspection of the glass discloses the presence in it of tiny whitish enamel-like portions, that probably mark the positions of some refractory particles that were not completely fused, and the existence of numerous small pores that may represent the original spaces between the grains.

The corrugations noted by Mr. Merrill* in the fulgurites from Whitesides Co., Ill., are very noticeable in the Waterville specimen, but instead of running longitudinally, as in the first case, they possess a slightly spiral twist in opposite directions on opposite sides of the tube. These corrugations or "wings" are covered with little knobs, that are hollow spaces enclosed within walls of glass and sand. Only in these knobs, however, are the ridges hollow. Throughout their greater extent the "wings" are merely a single layer of glass to both sides of which sand grains adhere in large numbers. The continuity of the glass across the corrugations seems to lend credence to the view of Merrill, that these irregularities on the surfaces of sand-fulgurites are due, not to the collapsing of the walls of the tube, as suggested by Wichmann, but to the selective power of the electricity in directing its course through the sand. That the corrugations are original structures, due to the action of the electric current, rather than accidental ones, is also indicated by their spiral twist (see figure).

Unfortunately insufficient material forbade analyses of the various portions of the tube, and its fragility would not admit of thin sections being cut from it, so a small fragment was crumbled between the fingers, and the resulting particles were examined under the microscope. The glass could easily be distinguished from the grains of sand. Some of the glass fragments were perfectly colorless, others were greenish, and all were filled with little air bubbles. No microlites of any kind were seen in them, but occasionally a small unfused sand grain could be detected imbedded in a perfectly isotropic matrix.

* Proc. U. S. Nat. Mus. for 1886, p. 85.

ART. XLII.—*Mineralogical Notes on Brookite, Octahedrite, Quartz and Ruby;* by GEORGE FREDERICK KUNZ.

AN interesting discovery of minerals was made at Placerville, Eldorado Co., California, by Mr. James Blackiston, in a quartz ledge running north and south and dipping eastward about 45° to 50°. The rock of the ledge is partly decomposed and partly compact, and is traversed for perhaps a hundred feet by a vein of crystallized quartz varying from six to fourteen inches in width. This vein is also decomposed and filled in with a reddish earth and sand, and can be dug into with a stick or board. It is full of quartz crystals, of all sizes from that of a man's finger up to remarkable dimensions, some of them weighing as much as 80 or 90 pounds. Several of these, over fifty pounds in weight, were pellucid and free from flaws: while others have peculiar interest from remarkable inclusions of chlorite, three to five millimeters in thickness, at several depths in the crystal—thus marking successive stages of crystal-growth, and making very striking "phantoms," generally of green chlorite, or white quartz layers. Of still greater interest, however, are other quartz crystals, two to four inches long and half that amount in diameter, containing at and near their centers inclusions resembling groups or clusters of dolomite or siderite crystals, cream-white to brown in color, and consisting of many curved rhombohedra from two to four millimeters in diameter. On breaking the specimens, however, the curious fact appears that these groups are hollow cavities in the quartz, the spaces being lined with a layer of chalcedony, or when brown, occupied only by a brown siliceous material. This would indicate that the original mineral must have been siderite or ankerite, afterward covered up by successive growths of the quartz, and in some manner decomposed during that process.

After receiving some of these specimens, the present writer detected a small crystal of octahedrite adhering to one of the small quartz crystals. Search was then instituted at the locality, which resulted in the discovery of a number of crystals of both octahedrite and brookite, some loose and some attached to the quartz. The octahedrite is in splendent crystals, from two to five millimeters in length, and varying in color from brown to almost a dark blue. Their form is that of the unit pyramid slightly distorted by horizontal striation.

The brookite is similarly implanted on the quartz, and partly or wholly overgrown by it, so as in some cases to be a true inclusion. The crystals are tabular, about two millimeters broad and one-fourth of a millimeter in thickness. Their color

is a rich reddish or yellowish brown, and they are free from inclusions. In form and association they closely resemble brookites from the Tyrol and from Maderananthal, Switzerland, lately described by P. Groth,* von Zepharovich† and Zimányi ‡ The following planes were kindly identified for me by Dr. S. L. Penfield of Yale University.

a,	100,	$\dot{\imath}$-$\bar{\imath}$	*t*,	021,	2-$\bar{2}$	*n*,	121,	2-$\frac{2}{3}$
c,	001,	*O*	*x*,	102,	$\frac{1}{2}$-$\bar{\imath}$	*ε*,	134,	$\frac{3}{4}$-$\frac{3}{5}$
l,	210,	$\dot{\imath}$-$\bar{2}$	*y*,	104,	$\frac{1}{4}$-$\bar{\imath}$	*Q*,	234,	$\frac{3}{4}$-$\frac{3}{2}$
m,	110,	*I*	*e*,	122,	1-$\bar{2}$			

The faces were small but gave him sufficiently distinct reflections for the identification of the forms; the pinacoid *a* is vertically striated. A distinct pleochroism was observed for vibrations parallel to *a* pale yellow, and parallel to *c* reddish yellow. Small crystals of an asparagus-green epidote 2^{cm} long and 2^{mm} in diameter were also observed partly enclosed in the crystals of quartz.

Among a quantity of minerals brought to me for sale by peasants at Ujakova, in the government of Perm, Ural Mountains, was a crystal weighing 25·4 grams, which was offered as garnet, but I at once recognized it as a monazite of remarkable size. This crystal measures 33 millimeters in breadth, 17 millimeters in length, and 11 millimeters in width, and presents a simple form, showing the planes *c* (001, *O*), *a* (100, $\dot{\imath}$-$\bar{\imath}$) and *m* (110, *I*). I was told that one of the Romanovskys, Russian mineralogists,—but which one I cannot ascertain—had purchased two of these so-called "garnets" implanted on crystals of albite, and one had been found at the same locality some time before.

Owing to the exploration at the ruby mines of Burma during the last few years a number of very large ruby crystals have been found in the ruby mines on the Moguk near Mandalay, Burma. Some of these have weighed from 300 to 2,000 carats —61 to 410 grams each; but they have all been translucent, or only transparent in small spots, affording but little fine ruby for cutting. They have, however, been cut up into very interesting ruby asterias and poor colored ruby gems. One crystal examined by the writer was a perfect hexagonal prism measuring 29^{mm} in height and 31 to 33^{mm} across the basal plane, which was broader than the length of the crystal. It was doubly terminated, and had trihedral rhombohedral markings on each basal plane, visible also on the prismatic faces. This crystal weighed several ounces and was valued at some £200.

My thanks are due to Dr. S. L. Penfield for his crystallographical determinations.

* Min. Samml. Strassburg, p. 110. † Zeitschr. Kryst., vol. viii, p. 577.
‡ Földtany Közlöny, xxi, p. 1.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Existence of Suspended Matter in Flames.*—It has been observed by Stokes that when a beam of sunlight, condensed by a lens, is passed through a candle-flame, the area of intersection of the double cone of light with the luminous envelope is marked by two brighter patches of light of inappreciable thickness which exhibit the polarization of light scattered by fine particles—that is to say, when viewed in a direction perpendicular to the incident light it is polarized in a plane passing through the beam and the line of sight. These patches can be made more conspicuous by viewing the whole through a cell containing copper-ammonium sulphate solution, or through cobalt-glass. The same phenomenon is shown by a luminous gas or ether flame but not by the blue base of a candle flame or by a Bunsen flame, even when rendered luminous with sodium chloride, or by an alcohol flame or by an ether flame just expiring for want of air. The separation of carbon, or carbon associated with hydrogen, thus rendered evident by its polarizing effect on light, is due to the action on the volatile carbon compounds, in the absence of a sufficient supply of oxygen to effect complete combustion, of the heat evolved by the more complete combustion at the base of the flame. In the case of the dying ether flame, the heat is probably distributed over too large a mass of inert gases to effect the decomposition. The thinness of the stratum of glowing carbon is probably due to the combined attack of oxygen on the outside and carbon dioxide on the inside.—*Chem. News*, lxiv, 167; *J. Chem. Soc.*, lxii, 111, February, 1892. G. F. B.

2. *On the use of Surface Tension in Analysis.*—It is well known that any liquid may be made to roll upon itself in drops, these drops being separated from the main body of the liquid by a thin stratum of vapor. Gossart has applied this fact to the detection and estimation of impurities in liquids, and finds it of special value in the case of spirituous liquors. For this purpose a drop is allowed to fall from the height of a millimeter upon the concave meniscus at the edge of the vessel containing the liquid. It is preferable to use a vessel having sloping sides so that the meniscus has a hyperbolic section. By the addition of such substances as citric acid or glycerin, the liquid is rendered viscous. If two pure liquids be used, the separating film of vapor is immediately absorbed and the drops of one liquid never roll upon the other. If however the supporting liquid contains an impurity, test drops of this same liquid will roll upon the supporting liquid, provided either that the two liquids contain the same percentage of the same impurity, or that this percentage varies only within fixed limits. With care these limits can be so far reduced that it becomes possible to find the amount of impurity present

within one five hundredth of the whole. Each impurity behaves as if it alone were present.—*C. R.*, cxiii, 537; *J. Chem. Soc.*, lxii, 286, February, 1892. G. F. B.

3. *On certain Metallic Hydrosulphides.*—On critically examining certain metallic sulphides precipitated in the ordinary way, LINDER and PICTON found that they contained combined hydrogen sulphide, forming in some cases definite and stable compounds. Moreover, higher hydrosulphides were also obtained, of high molecular mass, which under the influence of acids undergo condensation with elimination of hydrogen sulphide and which form solutions of moderate strength. When neutral solutions of certain metallic salts are allowed to run into a solution of hydrogen sulphide in excess, a solution is obtained, clear by transmitted light, which in some cases can be freed from its uncombined hydrogen sulphide by a current of hydrogen without causing precipitation. Acids, however, and metallic salts of inorganic acids, caused precipitation. To eliminate the production of acids the metallic hydrates or sulphides suspended in water were treated with hydrogen sulphide and solutions were obtained which were clear by transmitted light although strongly fluorescent. The authors conclude (1) that almost all the metals precipitable by hydrogen sulphide are capable of forming hydrosulphides, (2) that in some cases they are definite compounds fairly stable though of high molecular mass, (3) that acids cause these hydrosulphides to lose a part of their hydrogen sulphide, thus producing compounds of progressively higher molecular mass, (4) that by dissolving the precipitated sulphides in hydrogen sulphide water solutions are obtained which show no tendency to deposit any precipitate even after months of standing, (5) that these experiments support the conclusion that sulphides themselves are in most cases polymerides of a very high molecular mass, (6) that hydrosulphides of copper $(CuS)_7 . H_2S$, $(CuS)_9 . H_2S$, $(CuS)_{22} . H_2S$, and hydrosulphides of mercury $(HgS)_{31} . H_2S$ and $(HgS)_{62} . H_2S$ have actually been obtained, and (7) that bismuth seems incapable of forming a hydrosulphide.—*J. Chem. Soc.*, lxi, 114, February, 1892. G. F. B.

4. *On the Physical Constitutions of certain Sulphide Solutions.*—PICTON has submitted the hydrosulphide solutions, obtained as above, to a careful examination in order to test the question whether they are actual solutions or whether they contain the solid only in a very fine state of suspension. An arsenide acidified with hydrogen chloride and the liquid allowed to run into hydrogen sulphide water, readily gives a solution containing about five grams of sulphide in the liter; while in the case of mercuric sulphide thus treated, the solution contains ten grams to the liter. Examined with the microscope, under a power of 1000 diameters, the entire field is seen to be filled with exceedingly minute particles in very rapid Brownian movement. On filtration through a porous cell, the liquid came through colorless. Two solutions were obtained with arsenic; one (α) prepared by

running a solution of arsenous oxide in acid potassium tartrate into hydrogen sulphide water, the other (β) by similarly treating a solution of arsenous oxide in caustic soda. Both these solutions have a clear yellow color by transmitted light and are strongly fluorescent. The β solution keeps rather better, depositing only a trifling precipitate in a year. On microscopic examination, solution α was barely resolved with 1000 diameters, solution β not at all. By diffusion, it was observed that the tartrate in solution α carried out the arsenic particles by its own diffusion. Using Graham's method for solution β, the solution, contained in a wide-mouthed bottle, being placed in a large beaker and covered with water, it was found that after 32 days there was no sign of diffusion; the water remaining colorless and containing no arsenic. Evidently the whole of the sulphide is in a state of suspension. Antimony hydrosulphide solution has a fine orange-red color, only slightly fluorescent. No particles could be detected by the microscope at first, but after dialyzing for ten days they appeared, the whole of the sulphide being precipitated when the dialysis became complete; showing a progressive condensation. No diffusion was observed into a tartrate solution, but when a calcium light beam was sent through the antimony solution, as in Tyndall's experiment, the track of the beam was marked by a beautiful soft red glow, the light of which was completely polarized. Hence the solution has no true fluorescence, but consists of exceedingly minute particles in suspension. No filtration of the solution took place through a porous cell, nor did its coagulation develop heat. A third arsenic solution γ was then prepared, from an aqueous solution of arsenous oxide. It resembles the other arsenic solutions, but is stronger containing 11 or 12 grams of sulphide in a liter. Only a mere trace of precipitate occurred in four months. Under the microscope no particles could be detected, but distinct diffusion was observed. The beam of light gave a soft yellow glow completely polarized. The author concludes that "there seems to be no satisfactory reason for imagining the existence of any sharp boundary between solution and pseudo-solution. It is quite possible that the one merges by imperceptible gradations into the others."—*J. Chem. Soc.*, lxi, 137, February, 1892. G. F. B.

5. *On Solution and Pseudo-solution.*—Continuing the above researches, PICTON and LINDER have studied the character of a variety of colloidal solutions. The solutions of mercury, antimony and arsenic hydrosulphides already examined present a series passing from matter in a state of subdivision not too fine to allow of its observation under the microscope, to particles so fine as to diffuse after the manner of ordinary solutions. Indeed arsenic α is made up of particles just visible under the microscope, arsenic β contains no visible particles, while arsenic γ consists of particles so minute as to be diffusible. Mercuric sulphide dissolves in hydrogen sulphide water, and the vibrating particles are readily seen under the microscope. This state of pseudo-solu-

tion may possibly merge gradually into that of true solution by carrying the subdivision farther and farther until finally perhaps we may have the substance dissociated into ions. Graham supposed the non-dialyzability of colloids to be due to the size of their molecules, which were too large to pass through the pores of the membrane. Of the colloidal solutions examined by the authors, ferric hydrate, dissolved in ferric chloride, yielded a fluorescent solution in which no particles could be detected under the microscope, but which showed a dense polarized glow when examined with a beam of light. After being dialyzed, it could not be filtered through a porous cell nor did it diffuse in water. In presence of hydrogen chloride, silicic acid showed no luminous beam and passed readily through a porous cell. A dialyzed portion gave a feebly luminous beam. Molybdic acid gave only a very faint track of light. Cellulose dissolved in Schweitzer's solution showed a well marked glow as did also soluble starch. The latter solution did not diffuse. Congo-red in neutral solution gave a well marked polarized luminous beam but did not diffuse nor filter through a porous cell. In alkaline solution it filtered through a porous cell, but showed no luminous beam. Oxyhæmoglobin in water gave a luminous beam perfectly polarized, but did not filter through a porous cell. Magdala-red gave a non-polarized beam and readily filtered through a porous cell. In these experiments we pass from obvious suspension to colloidal solution, from colloidal solution to non-electrolytic crystallizable solution and from these it is probably only one step farther to electrolytic solutions. This change may be regarded as continuous. The case however is not one of mere suspension. There must surely be some attraction chemical in its nature, between the molecules of water or of hydrogen sulphide on the one hand and those of mercuric sulphide on the other. So that in every case of so-called very fine suspension there is a certain degree of molecular attraction between the suspended solid and the solvent. The authors therefore consider that they have made out a good *primâ facie* case for the belief that there is a continuous series of grades of solution passing without break from suspension to crystallizable solution.—*J. Chem. Soc.*, lxi, 148, February, 1892.

G. F. B.

6. *Methods of Gas Analysis.* By Dr. WALTHER HEMPEL. Translated from the 2d German Edition by L. M. DENNIS. 12mo, pp. xvi, 384. London and New York, 1892 (Macmillan & Co.). —Those who have favorably known Dr. Hempel's book in the original will welcome its appearance in English; especially so since the translation has had the benefit of the author's personal revision. It is a standard book on the subject of gas analysis and in the new edition, the improved method of air analysis devised by Pettersson is given. There is also a valuable chapter on determining the calorimetrical power of fuel. The translator has presented the author's meaning clearly and accurately.

G. F. B.

7. *Leçons sur les Metaux.* Par ALFRED DITTE. Second Fascicule, 4to, pp. 64, 667. Paris, 1891. (Vve Ch. Dunod.)—We have already noticed the first part of this excellent and exhaustive work. The second part sustains fully the high standard of excellence previously attained. It begins with magnesium, zinc and cadmium, then treats of the iron group of metals, and of aluminum, then considers the rare elements of the cerium and yttrium groups, then antimony, tin, bismuth, tungsten, molybdenum, vanadium, silver, lead, mercury, copper, gold and the platinum group. As in the earlier part the thermochemical relations are given in each equation and the reactions of formation of compounds are well developed. G. F. B.

8. *Solutions* by W. OSTWALD, Leipzig; being the Fourth Book with some additions of the second edition of Ostwald's Lehrbuch der allgemeinen Chemie. Translated by M. M. Pattison Muir, Cambridge. 316 pp. 8vo. London and New York, 1891 (Longmans, Green & Co.) The subject of solutions is at once one of the most interesting and difficult of those which belong in common to Physics and Chemistry. It is one, moreover, in which very rapid progress has been made of recent years largely as based upon the theory of solutions founded by van't Hoff. The presentation of the whole subject in its modern form is hence a great service to English-speaking students and this work must receive from them a warm welcome. As stated above, the volume is a translation of part of the last edition (1890) of Ostwald's great work on Chemistry, and has gained greater unity and completeness from the able work of the English editor as well as through the revision by the author.

II. GEOLOGY AND NATURAL HISTORY.

1. *Ueber Tertiärpflanzen von Chile;* von H. ENGELHARDT. Abhandlungen der Senckenbergischen naturforschenden Gesellschaft, Band xvi, Frankfurt a. M., 1891, S. 629–692, pl. i–xiv. —This memoir, announced a year earlier in Isis, describes the fossil plants collected by Dr. Ochsenius chiefly at Coronel and Lota in the province of Concepcion on the bay of Arauco, west coast of Chili, a few from Punta Arenas in the Straits of Magellan. The deposits are of Tertiary age, believed by the author to be Lower Miocene (Oligocene) or possibly Upper Eocene. One hundred and one species are distinguished, only one of which, *Chondrites subsimplex* LX., from the Laramie of Raton mountain, New Mexico, was previously known. There are four ferns, one cycad, two palms, one conifer (Sequoia), one unnamed species of Ephedra, and two fruits (Carpolites); the rest are all dicotyledons and consist of leaf impressions only, many of which, however, are well preserved. In determining these latter the author has been guided by the hypothesis that they ought to represent the ancestors of now living South American forms, and has referred the greater part of them to genera inhabiting that continent, chiefly

its tropical parts, arguing that they have migrated northward in later times with the gradual advance of the reduced temperatures in temperate latitudes. The deposits were laid down, according to him, anterior to the Andean uplift, and the genera represent mainly hydromegatherms of Candollean nomenclature, probably grown on low shores or islands in a warm moist climate. Whether he has carried this theory too far can only be decided by the subsequent discovery of more abundant material from these and other deposits. Certain it is that its adoption in this work furnishes a new basis for future investigations and can but lead to important results. For example, it must suggest to those engaged on the fossil floras of the Rocky Mountain region of North America the importance of comparisons with tropical American genera. Hitherto very little has been done in this direction and our investigations have followed too closely the lines of European authors. Many of the Chilian forms bear a close resemblance to some of the most problematical ones from the Fort Union and Laramie groups, as yet chiefly unpublished. Among these are some of those referred by Engelhardt to Tetracera, Triumfetta, Ouratea (Gomphia), Casearia, Myristica, Phœbe, Omphalea, and Algernonia (Tetraplandra), which have not hitherto figured in North American paleobotany. L. F. W.

2. *Miocene Plants from Northern Bohemia — Ueber fossile Pflanzen aus tertiären Tuffen Nordböhmens;* von H. ENGELHARDT. Ges. Isis in Dresden.—Abhandl. 3, 1891, pp. 20–42, pl. i.— *Ueber die Flora der über den Braunkohlen befindlichen Tertiärschichten von Dux;* von H. ENGELHARDT. Nova Acta der Ksl. Leop.-Carol. Deutschen Akad. d. Naturforscher, Bd. lvii, No. 3, 1891, pp. 131–219, pl. iv–xvii.—There is no one to whom the science of fossil plants is more indebted in these days than Prof. Engelhardt for making known the rich Tertiary floras of different parts of the world. His investigations are always painstaking and his illustrations are exceedingly clear and true to nature. In these two papers he gives another chapter of the interesting history of the ancient vegetation of northern Bohemia, already pretty thoroughly brought out by his previous labors and those of Ettingshausen and others. Seventy-nine species are treated in the first, four of which are new. They come from four different localities: Liebwerd, Duppau, Holaikluk, and Salesl. The lignites of Dux, treated in the second and much larger memoir, yield him 177 species and form the subject of an exceedingly important contribution. He gives the history of the working of these coal or lignite mines, dating back as far as 1566, and of the accumulation of the paleontological material, chiefly fossil plants, which has now been placed in his hands for determination. A large number of the species are new to science, but the majority were previously known, and from these he concludes that the deposit represents the Middle Miocene or Helvetian stage. A remarkable fact is that he finds American types to predominate, thus confirming the current glacial theory of subsequent dispersion, by

which Europe, on account of the east and west trend of its mountain ranges was cut off from the reception of the polar types in their return from the more southern regions into which they had been crowded by the ice sheet. This renders these forms specially important to the student of American pre-glacial floras, and many of them exhibit close relationships to those of our western deposits. L. F. W.

3. *Calcareous Algæ.—Fossile Kalkalgen aus den Familien der Codiaceen und der Corallineen;* von Herrn ROTHPLETZ in München. Zeitschr. d. Deutsch. geol. Ges., Bd. xliii, 1891, S. 295–322, pl. xv–xvii.—Dr. Rothpletz has here monographed, chiefly from the standpoint of their internal structure, the two families of fossil Algæ named in the title so far as his material would permit, confirming the views of Meunier-Chalmas and others, that many of the objects heretofore classed with the Foraminifera and other animal groups are really plants. The forms treated are referred to the three genera Sphærocodium, Girvanella, and Lithothamnium, of the last of which he describes fourteen species, and of the other two one each. They range from the Rhetic to the Pliocene, but the *Girvanella problematica* comes from the Ordovician of Ayrshire and was treated by Nicholson, Etheridge and Wethered as of doubtful affinities. L. F. W.

4. *On the Fructification of Bennettites Gibsonianus*, Carr.; by H. GRAF ZU SOLMS-LAUBACH. Annals of Botany, vol. v, November, 1891, pp. 419–454, pl. xxv, xxvi.—A notice of this memoir as it appeared in the Botanische Zeitung in 1890 will be found in this Journal for April, 1891 (vol. xli, p. 331). As it is based entirely on English material the editors of the Annals have regarded it as worthy of reproduction in English for the benefit of its readers for whom it might be otherwise inaccessible. The translation was intrusted to Mr. H. E. Garnsey of Magdalen College, Oxford, who has recently translated the Count's *Einleitung in die Phytopaläontologie.* As was pointed out in a recent review of his translation of the latter work (Science, vol. xviii, Dec. 25, 1881, p. 361), this memoir contains important modifications of the views of the author therein expressed which should have been introduced into the English edition. L. F. W.

5. *Le Nelumbium Provinciale des Lignites Crétacés de Fuveau en Provence;* par le Marquis G. DE SAPORTA. Mémoires de la Soc. Géol. de France, tome i, Fasc. 3, Mém. No. 6, Paris, 1890, pp. 9, pl. xii–xiv.—These deposits have hitherto furnished very little paleontological evidence of their age which has been in considerable doubt. M. de Lapparent placed them in the Danian or extreme upper Cretaceous above the Maestricht beds, while the present author regards them as occupying the level of the Gosau chalk equivalent to the Campanian of the French geologists. The remarkable aquatic plant here described cannot be said to throw much light on this question although it bears the marks of a greater antiquity than any other of its kind thus far found in the fossil state. But besides the Nelumbium, the Marquis Saporta

figures in this paper from the same beds several other apparently aquatic plants, a palm and three conifers. Two of these latter, *Frenelopsis Hoheneggeri* and *Geinitzia cretacea* are indicative of an even earlier period. L. F. W.

6. *Recherches sur la Végétation du niveau Aquitanien de Manosque;* par le Marquis G. DE SAPORTA. Mémoires de la Soc. Géol. de France, tome ii; I, Nymphéinées, Fasc. i, Mém. No. 9, pp. 22, pl. iii–vi; II, Palmiers, Fasc. 2, Mém. No. 9, pp. 23–34, pl. ix–xi.—The first of these papers treats of some important recent discoveries of Nympheaceous plants in the beds of Manosque, Céreste, and Bois d'Asson, chiefly by local collectors, the principal of whom are M. Nalin and Mlle. Rostan. The flora of these deposits as previously published by the author is reviewed and the new species described and fully illustrated. These include five species of Nymphæa, one of Anœctomeria, and one of Nelumbium. Associated with these was found a Ceratophyllum (*C. aquitanicum*), and the view is expressed that this anomalous genus is really related to the Nymphæaceæ. This view had already been suggested by Brongniart based on the similarity of the seeds, but most authors put this genus in an apetalous order by itself, though Baillon places it in the Piperaceæ. The second of those memoirs deals in like manner with the palms of these collections, of which there is one species each of the genera Flabellaria, Sabal, and Phœnicites. The author indulges in some important speculations upon the origin and development of these elements of the European Tertiary flora and its relations to that of the present day.

L. F. W.

7. *The Fauna of British India, including Ceylon and Burma.* Mammalia, Part II, by W. T. BLANFORD, F.R.S. Published under the authority of the Secretary of State for India in Council.—Part I. of Dr. Blanford's systematic work on the Mammals of India appeared in 1888, and is noticed in vol. xxxvi, of this Journal. This Second Part of this valuable treatise which concludes the work, making in all a volume of 618 pages, contains descriptions of the Cheiroptera, Rodentia, Ungulata (including the Pachydermata and Ruminantia of Cuvier), Cetacea and Edentata. Many figures illustrate the volume.

8. *Inheritance of Acquired Characters.*—Presidential address of D. G. ELLIOT, at the Annual Meeting of the American Ornithologists' Union, N. Y., Nov. 8, 1891, 28 pp. 8vo. From the January number, vol. ix, No. 1, of the Auk.—This address presents facts chiefly from ornithology in favor of the inheritance of acquired characters, making a successful argument against the views of Prof. A. Weissmann.

OBITUARY.

SERENO WATSON, Curator of the Harvard University Herbarium, died on March 9th, in his sixty-sixth year. A biographical sketch will be given in a following number.

APPENDIX.

ART. XLIII.—*Recent Polydactyle Horses;* by O. C. MARSH.

IN this Journal for June, 1879, the writer made a brief summary of the facts then known to him in regard to existing horses with extra digits, especially in relation to the extinct species he had discovered in the Rocky Mountains, and also gave figures of typical examples of existing and fossil forms.* Since then, he has collected much material bearing on the question, particularly of extinct horses, and an illustrated memoir on this subject has long been in preparation. Of recent forms, a number of polydactyle specimens have likewise been secured, some of which show new anatomical points of interest, and are discussed in the present communication.

In the article above cited, various recorded instances of extra digits in the horse are mentioned, some dating back to the beginning of the last century. A much earlier notice is the account of the famous steed of Julius Cæsar, given by Suetonius (*de vita Cæsaris*, LXVI), to which a classical friend has recently called the attention of the writer. According to the historian, Cæsar "used to ride a remarkable horse, which had feet that were almost human, the hoofs being cleft like toes. It was born in his own stables, and as the soothsayers declared that it showed its owner would be lord of the world, he reared it with great care, and was the first to mount it; it would allow no other rider."

It is now known to every one familiar with the modern horse, that the main, functional toe of each foot is the third digit, corresponding to the middle finger of the human hand and foot. In addition to these, two "splint bones," one on each side of the main cannon bone, are present beneath the skin. It is not so well known, however, that the latter are the remnants of two other toes possessed by ancestors of the horse.

* Polydactyle Horses, recent and extinct, this Journal, III, vol. xvii, p. 497, June, 1879; see also by the writer, New Equine Mammals from the Tertiary, Ibid., vol. vii, p. 247, March, 1874; Fossil Horses in America, Am. Naturalist, vol. viii, p. 288, May, 1874; and Introduction and Succession of Vertebrate Life in America, this Journal, vol. xiv, p. 338, November, 1877.

These slender metapodial bones still represent the second and fourth digits, and are shown in their usual position, in figures 1 and 2. One or more of these splint bones may become enlarged below, and support phalanges, forming another digit beside the main one, either beneath the skin, or, more commonly, developing into a small, external toe with hoof.

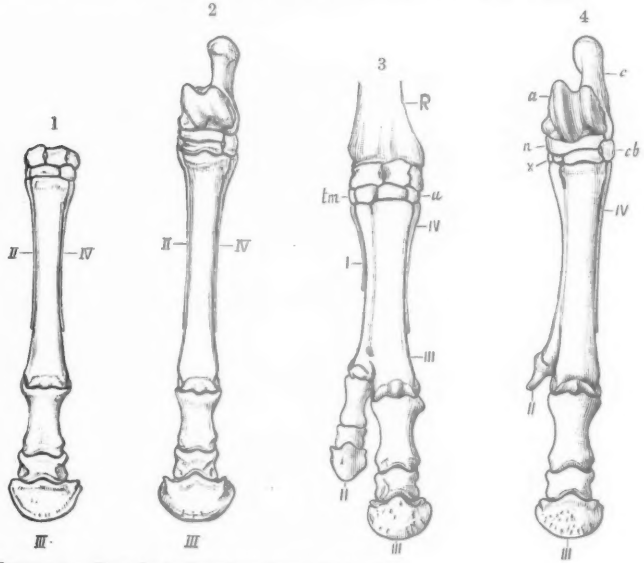


FIGURE 1.—Fore foot of modern horse (normal).
FIGURE 2.—Hind foot of same animal.
FIGURE 3.—Fore foot of "Clique, the horse with six feet" (polydactyle).
FIGURE 4.—Hind foot of same animal. All left feet, and one eighth natural size.
a, astragalus; *c*, calcaneum; *cb*, cuboid; *n*, navicular; *R*, radius; *tm*, trapezium; *u*, unciform; *x*, cuneiform; I. first digit; II. second digit; III. third digit; IV. fourth digit

The occurrence of such extra digits in the recent horse is much more frequent than is generally supposed. Since the attention of the writer was first called to the subject, he has seen and examined a large number of living animals with this peculiarity, and has had sent to him several interesting specimens of the same character. He has likewise received photographs, drawings, and detailed descriptions of various other examples, the authenticity of which cannot be questioned. This material, together with not a few published accounts, forms a fair basis on which to investigate the subject. This, however, would require much time in itself, especially if it led into the question whether polydactylism is atavism, and other

allied topics. In the present paper, it is intended merely to state the more important facts, and what they indicate, leaving the full discussion for another occasion.

The cases of supernumerary digits in the existing horse now known to the writer may be roughly classified, as follows:

(1) An extra digit on one foot. This is always much smaller than the main, or third, digit, the largest seen being about one half its size, and the smallest, very diminutive. This extra toe is almost invariably on the inner side of the main digit, and usually on the fore foot. Not infrequently it may be entirely beneath the skin, the only external evidence of it being a prominence, which, on close examination, will often be found to contain, below the splint bone, two or more movable phalanges, but sometimes only a single one, and very small.

(2) A corresponding extra toe may be present on the other fore foot, equally developed with the opposite one, but occasionally much smaller, or even concealed under the skin.

(3) A second extra digit may exist with those above described, but outside the main digit. This toe, as a rule, is smaller than the inner one, but may equal or exceed it.

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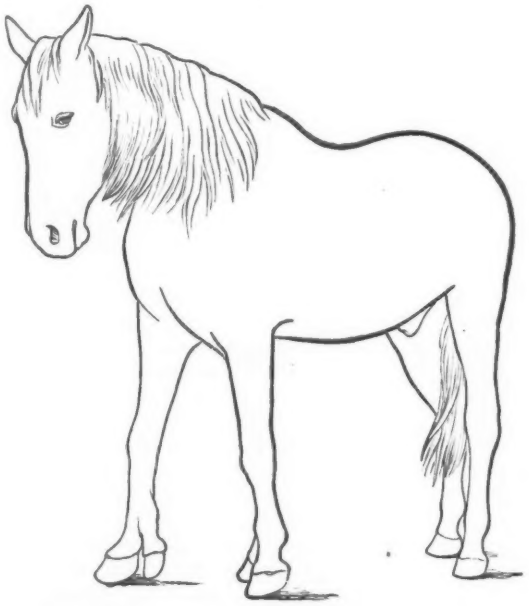

FIGURE 5.—"Clique, the horse with six feet," showing two extra digits.

(4) With the extra inner toes of the fore feet, another of equal or smaller size may be present on one or both of the hind feet, almost always on the inside. Usually, however, these posterior toes are much smaller, and often beneath the skin, when the anterior extra digits are well developed. An example of the equal development of all the inner toes, fore and aft, is shown below in figure 6, which represents an animal examined during life, by the writer. Occasionally the hind feet may each have two extra digits, while the fore feet have only one, as in the horse shown in figure 7.

(5) In rare cases, both fore and hind feet may each have two extra digits fairly developed, and all of nearly equal size, thus corresponding to the feet of the extinct *Protohippus*, which are represented in the diagram on page 355.

(6) Sometimes, besides the extra toes above described (which appear to be always the second and fourth), the first digit, or pollex, may be represented by its metacarpal, supported by a distinct trapezium, all beneath the skin. In such cases, the fifth digit, corresponding to the little finger of the human hand, alone is wanting. Three examples of this four-toed polydactylism are preserved in the Yale Museum, and one of them is shown in figure 3. This type is of special importance, and is described more fully below.

The horse which best represents this type was examined casually by the writer when it was alive, and at its death was presented to him for the Yale Museum by the owner, Theodore F. Wood, of New Jersey. The animal was widely known to the general public as "Clique, the horse with six feet," having been exhibited for many years, in this country and in Europe. He was said to be from Texas, and at his death, in January, 1891, was very old. This horse, when alive, showed an extra digit of good size on the inside of each fore foot, and a corresponding prominence on each of the hind feet, but no free lateral toe. An outline of this horse is shown in figure 5.

The first digit of the fore foot, corresponding to the thumb of the human hand, was not apparent externally, but, by close examination, could be detected beneath the skin, where the upper part of the splint bone appeared as a ridge. The second digit was the free extra toe, which attracted especial attention from its large size, and pendent, elongated hoof. Its metatarsal is closely united to the main cannon bone, which thus seems much broader than usual. The fourth digit appears only as the usual splint bone, and of the fifth, there is no indication whatever. The hind feet showed no peculiarity except the inner prominence above the fetlock, formed by the lower end of the second metatarsal, with a single movable

phalanx and its sesamoid. In other respects, the limbs were well shaped, and in fair condition for so old a horse.

After the death of the animal, a careful dissection of the feet was made, and several points of interest became apparent. First of all, in the fore feet, the presence of the first digit was demonstrated by a robust, splint metacarpal about half the length of the main cannon bone. This splint was supported above by a large trapezium having the usual articulations of that bone in its full development. The first digit, as present in the left foot of this horse, is shown above in figure 3. In the opposite fore foot, this digit is also represented, and equally developed, as seen in figure 8.

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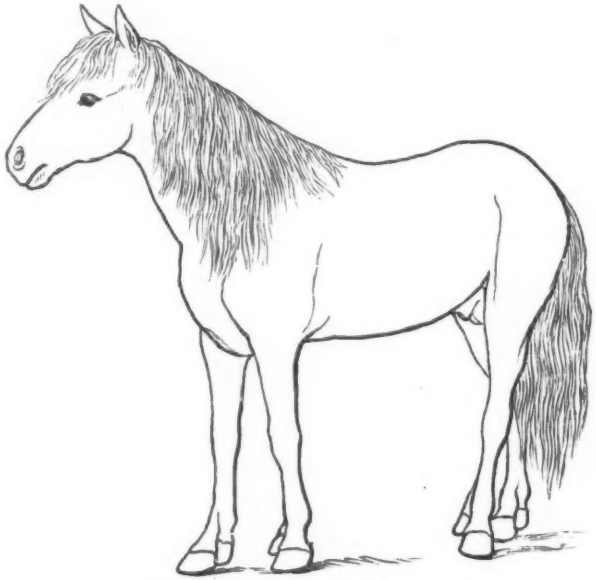


FIGURE 6.—"Eight-footed Cuban horse," with extra digit on each foot.

The second metacarpal of the left fore foot is quite large, and fully developed above and below, but its shaft is coössified with the main metacarpal. The line of the suture uniting the two is still strongly marked, as shown also in figure 3. The phalanges and sesamoids are all well developed, and had this toe been long enough to reach the ground, it would have afforded a strong lateral support to the main digit. The latter possesses no marked peculiarities except that the outer side is

more developed, especially in the coffin bone. The fourth digit is represented by a strong splint bone similar to that in the normal foot of the existing horse. The opposite fore foot appears to correspond in all respects with the one here described and figured.

The hind feet of this animal present some further points of importance. The first digit is wanting, but the first cuneiform bone is present, and well developed.* The second digit is represented by a strong, complete metatarsal, coössified along its main shaft with the large cannon bone of the third digit, but with both extremities free. It was supported above by

7

FIGURE 7.—"Horned horse from Texas," showing six extra digits.

* The name cuneiform as applied to the ulnare bone of the carpus is misleading, and should be discontinued, as the same word is used for two or more bones in the second row of the tarsus. The name pyramidal employed by many anatomists is not open to this objection, and its use for the ulnare is to be recommended.

two united cuneiform bones. The lower extremity of this metatarsal carried a single phalanx, with a posterior sesamoid evidently formed of two bones. The main cannon bone and its phalanges show no marked peculiarities except some obliquity. The fourth digit is represented by a large splint metatarsal, as shown in figure 4. The opposite hind foot appears to be similar in all respects, except that the three small cuneiform bones are separate, as shown in figure 9.

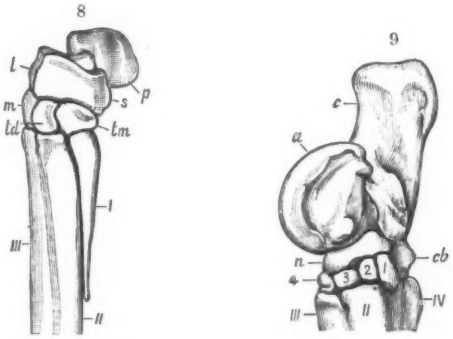


FIGURE 8.—Right carpals and metacarpals of "Clique."
FIGURE 9.—Right tarsals and metatarsals of same animal. One fourth natural size.
a, astragalus; *c*, calcaneum; *cb*, cuboid; 1, 2, 3, 4, cuneiform bones; *l*, lunar; *m*, magnum; *n*, navicular; *p*, pisiform; *s*, scaphoid; *td*, trapezoid; *tm*, trapezium.

In no case examined by the writer has there been conclusive evidence of any extra digit except one of a true pentadactyle foot, such as is now known in the ancestry of the horse. In every specimen examined, where the carpal or tarsal series of bones were preserved, and open to inspection, the extra digits were supported in the usual manner. No instances of true digital division were observed, although such cases might be expected. It is noteworthy that none of the extra toes examined represents the fifth digit, although the reappearance of this rather than the first might naturally be looked for. No digit has been noticed with more than three phalanges.

A large majority of the polydactyle horses known to the writer in this country, have been raised in the Southwest, or from ancestry bred there, so that their connection with the Mustangs or semi-wild stock of that region becomes more than probable. It is well known that the tendency to reversion is much stronger where animals run wild, and this fact must be taken into consideration in discussing the present question, for the late ancestors of the Mustang were certainly wild for at least several hundred years.

No example of extra digits has been observed by the writer in any wild species of existing equine mammals of the old world, or their immediate descendants, although it is evident that such cases are probable, and careful observation would doubtless bring them to light, especially if made in the native haunts of those animals.

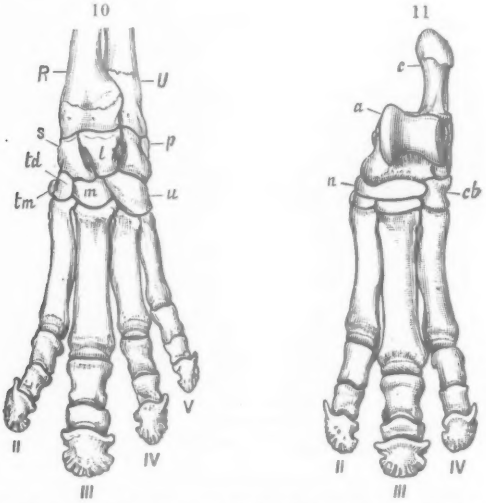


FIGURE 10.—Left fore foot of recent Tapir (*Tapirus indicus*, Cuvier).
FIGURE 11.—Left hind foot of same animal. One fifth natural size.

Many examples of polydactyle feet in the recent horse, preserved in museums, have been cut off below the carpus or tarsus, and thus the real significance of the extra digits has been lost. The whole carpal and tarsal series, and the distal ends, at least, of the bones above them, may be important elements in the problem to be solved, if reversion or atavism is to be considered.

In reviewing what is now known of the extra digits in the existing horse, a few points are manifest, which could not have been anticipated from previous knowledge of the perissodactyle foot:

(1) The presence of a first digit in the fore foot, represented by a strong, styliform metacarpal supported by a well-developed trapezium, with its usual articulation, in the same foot in which the fifth digit is wanting.

(2) The frequent appearance of the second digit as a distinct, free toe in one or more feet, and the large size it attains, while the other digits, except the third, are aborted or wanting.

(3) The presence of five distinct bones in the second row of the tarsus. One of these is the cuboid fully developed; next, the external cuneiform bone supporting the great metatarsal; then three smaller bones on the tibial side. These five tarsals correspond either to those in the reptilian foot, or the first may be regarded as a sesamoid, and the cuboid, as double (including the fourth and fifth), as it is now usually considered by anatomists. Another explanation may be suggested; namely, that the inner, pendent bone is a remnant of the first metatarsal. Such a rudiment apparently exists in some fossil horses, and its appearance in the hind foot of a recent animal which had the first digit of the fore foot so well represented would not be strange. The bone usually regarded as the inner cuneiform in the existing tapir and rhinoceros may, perhaps, include the same remnant. In the modern horse, this bone is sometimes double, but the specimen represented in figure 9 shows that it may be composed of three elements.

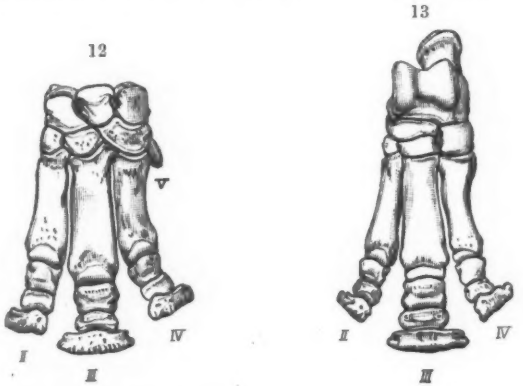


FIGURE 12.—Left fore foot of *Rhinoceros bicornis*, Linnæus.
FIGURE 13.—Left hind foot of same animal. One eighth natural size.

The frequent reappearance of the second digit as an extra toe in the modern horse would seem to indicate that this feature was functional in a late ancestor, but no fossil equine with two toes has yet been found.*

The presence of four toes in the fore feet, each supported by its true carpal bone, is a fact of much importance, and is clearly a case of reversion. The four distinct cuneiform bones

* A small species of *Pliohippus* from the Pliocene of Oregon may be an exception. An incomplete hind foot in the Yale Museum shows the second metatarsal as a splint bone, the third very long and slender, and the fourth so well developed that it probably supported phalanges. This may also be a case of reversion. The species is new, and may be called *Pliohippus gracilis*.

in the hind foot of the same animal offer another point of interest, especially in connection with the corresponding carpal series.

The hoofs of the extra digits of the modern horse vary much in size and form at birth, and are subsequently affected by the surroundings of the animal, and the care it receives. If these hooflets are low enough to reach the ground, their growth is checked by wear, like the large hoof, although in less degree. As the main hoofs will become of abnormal length, and more or less twisted, if the animal is confined to soft, boggy ground, so the extra hoofs having no wear, and receiving no pruning, often become much elongated and curved, or by trimming may assume the form of a spur or horn. The "horned horse from Texas," shown in outline in figure 7, probably received some attention of this kind, as the hooflets are much more pointed than any examined personally by the writer.

The cleft seen in the last phalanges, or hoof bones, of *Orohippus* and other fossil equines, and occasionally present in the coffin bone of the modern horse, is interesting, but of no special significance. It certainly does not represent the union of two digits, as frequently supposed, and sometimes asserted by scientific writers.

The tapir has the most primitive feet of existing perissodactyles, and most like those of the early predecessors of the horse. The feet of the Middle Eocene *Orohippus* were, in fact, very similar in structure, as will be seen by comparing the manus and pes of each as shown in figures 10–11, and 16–17. The living rhinoceros has feet of the same general type, but less primitive (figures 12–13), while the modern horse, when normal, has the extreme specialization of the monodactyle foot. The frequent reversion to extra digits indicates a polydactyle ancestry, which is now demonstrated by actual discovery.

The terms *Perissodactyla* (odd-toed) and *Artiodactyla* (even-toed) proposed by Owen, and now in general use to distinguish two great groups of hoofed mammals, are misleading, and a stumbling block to the lay reader, as well as to many popular writers on science. The horse, tapir, and rhinoceros are the only recent examples of the so-called perissodactyles, or odd-toed ungulates, and the pig and peccary are certainly typical artiodactyles. The tapir, however, has four toes in the front foot, while the peccary has three only behind, and these exceptions do not prove the rule, for the number of toes alone has nothing to do with the profound distinctions separating the two groups, at least in all recent forms.

In the horse and its allies, recent and extinct, the axis of each foot passes through the middle of the main, or third, digit, while in all the so-called even-toed mammals, the axis is always along the side of this digit. This is the essential difference between the feet of the two groups.

The names *Mesaxonia* (middle axis) and *Paraxonia* (side axis) proposed by the writer in 1879,* as substitutes for Owen's terms, are more exact definitions, but thus far have not met with general favor, for it seems almost impossible to dislodge an established error in science. The term "coral insect," for example, of the older writers, still maintains its place in popular science, and even in some modern text books.

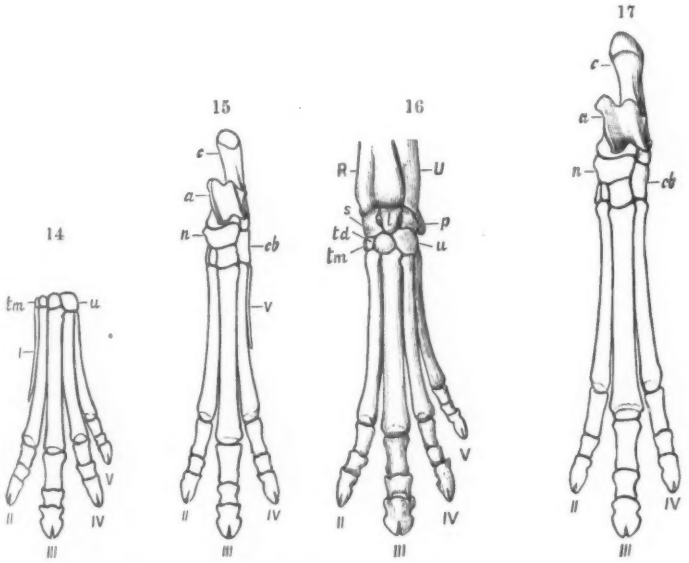


FIGURE 14.—Fore foot of oldest fossil horse, *Eohippus pernix*, Marsh.
FIGURE 15.—Hind foot of same. Lower Eocene.
FIGURE 16.—Fore foot of *Orohippus agilis*, Marsh (type).
FIGURE 17.—Hind foot of same. Middle Eocene. All left feet, one half natural size.

In explanation of the extra digits of the recent horse, two views have been advanced: (1) that they are reduplications of the main digit, like the occasional sixth finger of the human hand, or result simply from a division of this toe; (2) that they are true cases of reversion to a polydactyle ancestor. The former view was long held by writers on the subject, and

* This Journal, vol. xvii, p. 501, June, 1879.

is still maintained essentially by some eminent anatomists.* The large number of cases, however, now investigated by the writer make it probable that, for most instances, at least, the second explanation is the true one.

In the case of horses, recent and extinct, the question of atavism is much simplified, as they start with a pentadactyle form, and each successive change in the modifications of the limbs, and of the feet, and likewise in the dentition, can be traced through a regular series from the early Tertiary down to the present time. Nearly every instance of polydactylism

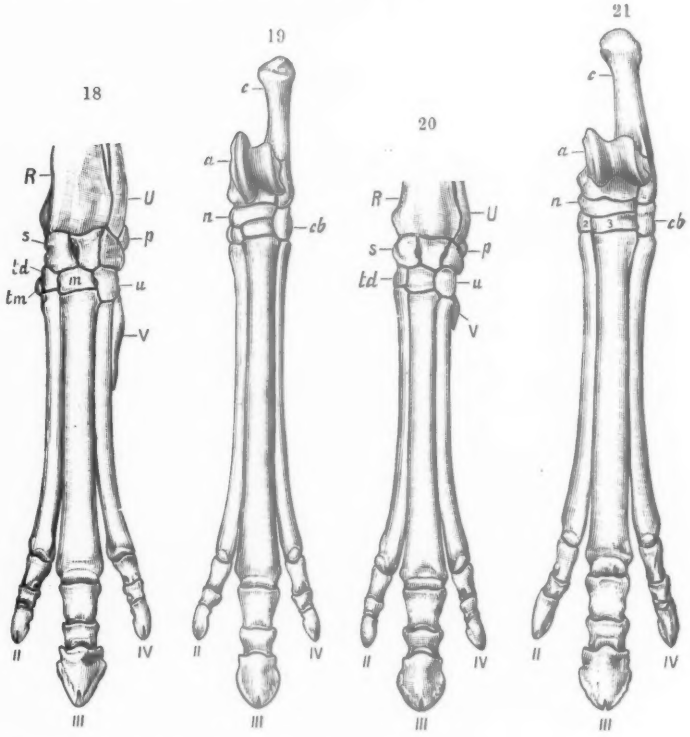


FIGURE 18.—Left fore foot of *Mesohippus celer*, Marsh.
FIGURE 19.—Left hind foot of same. One half natural size. Lower Miocene.
FIGURE 20.—Left fore foot of *Miohippus anceps*, Marsh.
FIGURE 21.—Left hind foot of same. One third natural size. Upper Miocene.

* Flower, Osteology of the Mammalia, p. 296, 1885; and Gegenbaur, Morphologisches Jahrbuch, p. 584, 1880.

observed in the modern horse has its counterpart in some extinct species now known, and it is not at all improbable that future discoveries will bring to light examples corresponding to the present apparent exceptions.

All the examples of polydactylism in the horse which the writer has had opportunity to examine critically are best explained by atavism, and many of them admit no other solution. Taken together with the fact now known of their great frequency, they clearly indicate the descent of the horse from comparatively recent polydactyle ancestry.

The writer has traced back the genealogy of the horse through various stages, to a form, *Eohippus*, in which all five toes were represented, and has likewise given an explanation of the change which in succeeding forms has reduced the number to one functional digit, as in the existing horse. It is in these extinct species that the true solution of the problems relating to the extra digits of the modern horse is to be sought. In the various papers cited at the beginning of the present article will be found the main facts relating to the ancestry of the horse as made out by the writer from American forms.

The oldest ancestor of the horse, as yet undiscovered, undoubtedly had five toes on each foot, and probably was not larger than a rabbit, perhaps much smaller. This hypothetical predecessor of the horse can now be predicated with certainty from what is known of the early hoofed mammals. It may be called *Hippops*, and its remains will be found at the base of the Tertiary, or more likely in the latest Cretaceous. A still more primitive ancestral form, and next older in the series of Ungulates, will show the more generalized characters of the group called by the writer *Holodactyla* (Dinocerata, p. 172), from which both the Perissodactyles and the Artiodactyles branched off before the equine line became distinct.

It is impossible to say from what generalized form the horse line first separated, but at present the probabilities point to a genus allied to the Eocene *Hyracotherium*, Owen (1839), as the stem. In the latter genus, the molar teeth are of the bunodont type, the tubercles being conical and distinct. Similar teeth are characteristic of suilline mammals, and from the teeth alone, the two groups could not be distinguished, but it is now probable that the latter appeared as a distinct group later than the equine mammals, and that their oldest representatives were very diminutive in size.

The American representative of *Hyracotherium* was first described by the writer under the name *Helohyus*,* and another form, nearly allied, as *Thinotherium*, all three being

* This Journal, vol. iv, pp. 207, 208, September, 1872.

at first supposed to have close affinities with suilline mammals. Some of the latter may, in fact, be included in the species referred to these genera. Various perissodactyle forms, also from the Eocene of this country, have since been described by Cope under the generic name *Phenacodus* (1873), which is clearly identical with *Helohyus*, and some of these have been referred, under the former name, to the equine ancestral line.* These mammals have been placed by the writer in a distinct family, the *Helohyidæ*.†

Helohyidæ.

The *Helohyidæ* may with some probability be now regarded as the family from which equine mammals were derived. The members of this group were small perissodactyle mammals, with forty-four teeth without cement, the premolars unlike the molars, and both with short bunodont crowns. The ulna and fibula were complete and separate, and the feet had four or five functional digits. All the known forms are from the Eocene. During Tertiary time, this family apparently separated into various branches, some of which became specialized, and died out, while smaller forms became modified into the lines by which the horse, the tapir, and the rhinoceros gradually developed.

Orohippidæ.

The successors along the first line form a well-marked family, which the writer has called the *Orohippidæ*.‡ The representatives of this group were small equine mammals having forty-four teeth without cement, incisors without pit, canine teeth large, and the molar series with short crowns, and the cusps more or less flattened. The ulna and fibula were complete, and there were three or four functional digits in each foot. The members of this family appear to be all from the Eocene or Miocene.

Equidæ.

Next in the succession came the *Equidæ*, of which the horse is a typical member. All are large equine mammals, with less than forty-four functional teeth with cement, incisors with pit, canines small or wanting, the molars elongated, and the premolars essentially like the molars. The ulna and fibula are incomplete, and there is but one functional toe on each foot. These mammals lived in Pliocene time, continued on to the present, and are now represented by the horse, ass, zebra, and quagga.

* W. H. Flower, The Horse, London, 1891; also, Madame Pavlow, L'Histoire Pal. des Ongules, I–V, Moscou, 1887–1890.

† This Journal, vol. xiv, p. 364, November, 1877.

‡ Ibid., vol. vii, p. 249, 1874.

The dividing lines between these three families are not sharply defined, and cannot be, if evolution is true; in fact, the divisions in all classifications of extinct animals are, of necessity, like the book shelves in a library, merely convenient stages for the arrangement of present limited knowledge.

Among the extinct equines known in this country, the first genus of the series is *Eohippus*, described by the writer from the Coryphodon beds at the base of the Eocene (this Journal, vol. xii, p. 401, 1876). This is the oldest and most diminutive form, being about the size of a small fox. There is a diastema between the canine and first premolar, but none between the premolars, which are all unlike the molars. Three species are known. The feet of one species are shown in figures 14 and 15, and those of the others so far as known are similar.

In the next higher horizon of the Eocene, remains of another small equine mammal are found, which may be placed in a new genus, *Helohippus*. The type specimen was described by the writer in 1871, as *Lophiodon pumilus* (this Journal, vol. ii, p. 38), and others have since been found in the same horizon. This genus has a diastema between the first and second premolars, and the last premolar is like the molars. The known representatives of *Helohippus* are about as large as a fox.

The next genus in the series is *Orohippus*, described by the writer from the Dinoceras beds of the Middle Eocene (this Journal, vol. iv, p. 207, 1872). This form is the type of the family *Orohippidæ*, and almost every part of the structure of several species is now known. The best preserved specimens show that there is no diastema between the upper premolars, and the third and fourth are similar to the molars. The skull is elongate, and has no antorbital fossa. The fore and hind feet of one species are shown in figures 16 and 17. Several other species are known, all about the size of a fox.

Another allied genus, *Epihippus*, occurs in the Diplacodon beds of the Upper Eocene. This genus, proposed by the writer in 1878 (Proc. Am. Assoc. Adv. Sci., page 236), also shows no diastema between the first and second premolars above or below, and the third and fourth are essentially like the molars. Two species are known, both somewhat larger than those of *Orohippus*, but having the same general structure, although the dentition and feet differ in several respects, being intermediate between that genus and the following.

At the base of the Miocene, in the Brontotherium beds, another equine mammal is comparatively abundant, and has been referred by the writer to a distinct genus, *Mesohippus* (this Journal, vol. ix, p. 248, 1875). The two species known are about as large as a sheep, and the feet of one are shown in

figures 18 and 19. The ulna is complete, but the fibula is not. There is no diastema between the premolars, and the third, fourth, and fifth are like the molars.

In the Upper Miocene of Oregon, the series is continued in *Miohippus*, a genus established by the writer in 1874 for several species found in this formation (this Journal, vol. vii, p. 249). All are much larger than *Mesohippus*, and more specialized in the skull and feet. The latter are shown in figures 20 and 21. The premolars form a continuous series, and three of them are of the molar type. This genus appears to be the American representative of *Anchitherium*, von Meyer (1844), but is somewhat less specialized.

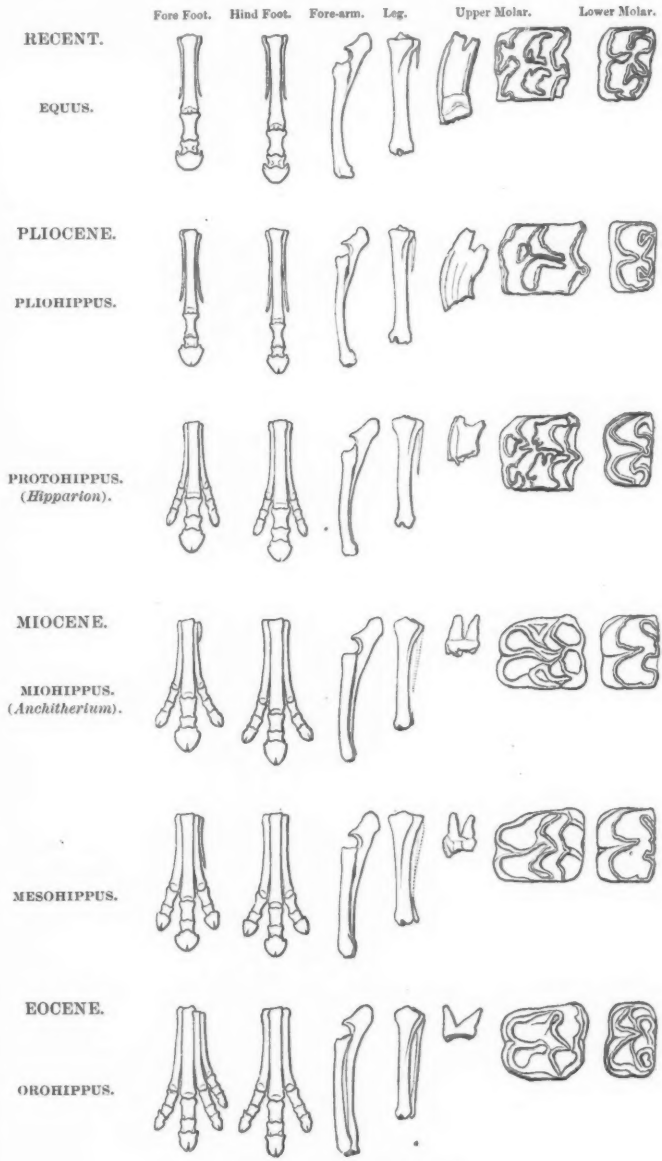
In the early Pliocene of this country, the genus *Protohippus* of Leidy (1858) is especially abundant, and several species about as large as a donkey are known. All have three functional toes on each foot, but these are more nearly of a size than the digits of the European *Hipparion* of Christol (1832). In the later deposits of this formation, three-toed horses are replaced by *Pliohippus*, named by the writer in 1874 (this Journal, vol. vii, p. 252). This genus has many species, all smaller than the horse, but with similar feet. A true *Equus* is entombed in a higher horizon, but apparently became extinct before America was discovered.

The type specimens of all the genera of fossil horses proposed by the writer up to 1876 were carefully studied by Prof. Huxley in that year, and made the basis of one of his New York lectures.* The diagram shown on page 355 was prepared for that lecture under his direction, from specimens in the Yale Museum collected and described by the writer. It gives the main characters of the genera, and represents clearly the evolution of the horse as then determined from American specimens.

Since then, the writer has made large collections of remains of these and other genera and species, and the whole forms by far the largest series ever brought together. An examination of this collection makes still more evident the line of equine descent on this continent, and the genera since named, and described (*Eohippus*, *Helohippus*, and *Epihippus*), help to complete the series. Many details are yet wanting, but the writer hopes at an early day to bring all the facts together, and make out as far as possible the genealogy of the horse.

New Haven, Conn., March 24th, 1892.

* American Addresses, p. 88, London, 1877.



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ROWLANDITE, A NEW MINERAL!

We have secured the entire available supply of this new and wonderfully interesting mineral (see A. J. S., Nov. '91). Mr. Hidden informs us that it probably contains **twelve new elements** (!!) and that its spectrum embraces 10,000 lines!! An elaborate description by Prof. Rowland and Dr. Hillebrand is promised soon. All the type material not needed for the examination has been purchased by us, and as there is altogether less than five pounds the supply will doubtless prove inadequate to meet the demand. The mineral is found only massive and our specimens are all excellent though necessarily of but medium sizes. Prices, $5.00 to $20.00.

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Probably the largest lot of good specimens of these two very rare minerals ever brought together is now in our store. We can furnish fairly good crystals of **Thorite** as low as $1.00 and up to $5.00, and splendid masses of **Orangite** at 50c. to $5.00. These prices are far below those at which these minerals have heretofore been sold.

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GEO. L. ENGLISH & CO., Mineralogists,

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CONTENTS.

Page

ART. XXXII.—Action of Vacuum Discharge Streamers upon each other; by M. I. PUPIN. With Plate XII ... 263

XXXIII.—Melilite-bearing Rock (Alnoite) from Ste. Anne de Bellevue near Montreal, Canada; by F. D. ADAMS.. 269

XXXIV.—Azure-blue Pyroxenic Rock from the Middle Gila, New Mexico; by G. P. MERRILL and R. L. PACKARD 279

XXXV.—Correlation of Moraines with Raised Beaches of Lake Erie; by F. LEVERETT 281

XXXVI.—Magnesium as a Source of Light; by F. J. ROGERS 301

XXXVII.—Method for the quantitative separation of Barium from Calcium by the action of Amyl Alcohol on the Nitrates; by P. E. BROWNING 314

XXXVIII.—Plicated Cleavage-Foliation; by T. N. DALE.. 317

XXXIX.—Geological Age of the Saganaga Syenite; by A. R. C. SELWYN 319

XL.—Third Occurrence of Peridotite in Central New York; by C. H. SMYTH, JR. 322

XLI.—Fulgurite from Waterville, Me.; by W. S. BAYLEY.. 327

XLII.—Mineralogical Notes on Brookite, Octahedrite, Quartz and Ruby; by G. F. KUNZ 329

APPENDIX.—XLIII.—Recent Polydactyle Horses; by O. C. MARSH 339

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Existence of Suspended Matter in Flames, STOKES: Use of Surface Tension in Analysis, GOSSART, 331.—Certain Metallic Hydrosulphides, LINDER and PICTON: Physical Constitutions of certain Sulphide Solutions, PICTON, 332.—Solution and Pseudo-solution, PICTON and LINDER, 333.—Methods of Gas Analysis, W. HEMPEL, 334.—Leçons sur les Metaux, A. DITTE: Solutions, W. OSTWALD, 335.

Geology and Natural History—Ueber Tertiärpflanzen von Chile, ENGELHARDT, 335.—Miocene Plants from Northern Bohemia, ENGELHARDT, 336.—Calcareous Algæ, ROTHPLETZ: Fructification of Bennettites Gibsonianus, GRAF ZU SOLMS-LAUBACH: Nelumbium Provinciale des Lignites Crétacés de Fuveau en Provence, G. DE SAPORTA, 337.—Recherches sur la Végétation du niveau Aquitanien de Manosque, G. DE SAPORTA: Fauna of British India, including Ceylon and Burma, W. T. BLANFORD: Inheritance of Acquired Characters, D. G. ELLIOT, 338.

Obituary—SERENO WATSON, 338.